Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JULY 1953

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HYDRO-ELECTRIC
POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
A Member of the A.E.I. group of companies
AX/A002

132-kV 3500 MVA FOUR-BREAK INDOOR CIRCUIT-BREAKER

REYROLLE
AIR-BLAST
SWITCHGEAR

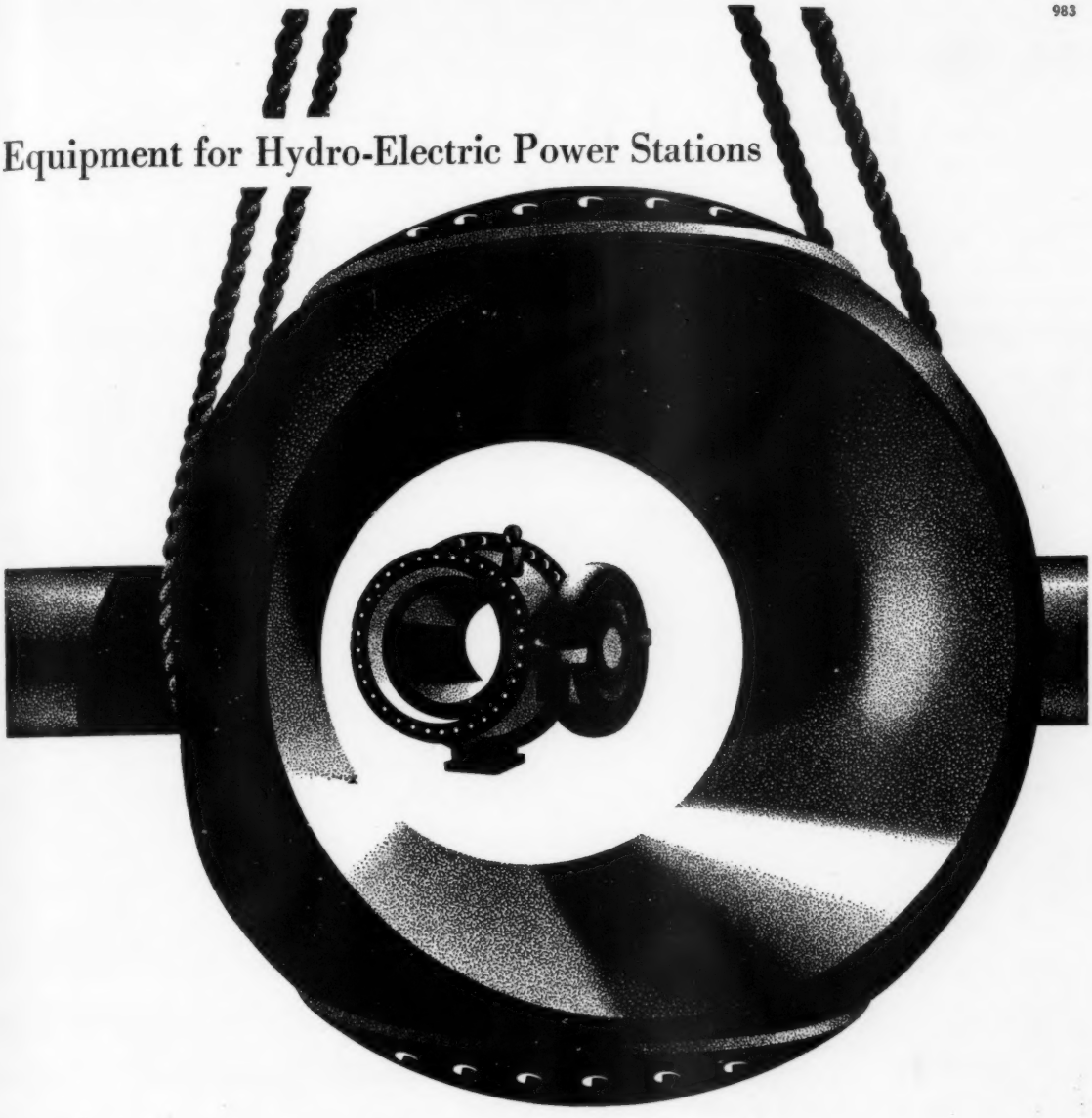
One phase from one of twenty-three circuit-breakers installed at Barking 'C' power-station

Consulting Engineers: Messrs. MERZ and McLELLAN

Reyrolle

A. REYROLLE & CO. LTD · HEBBURN · CO. DURHAM

Equipment for Hydro-Electric Power Stations



Rotary Valve as turbine valve, in front the spherical valve body

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.

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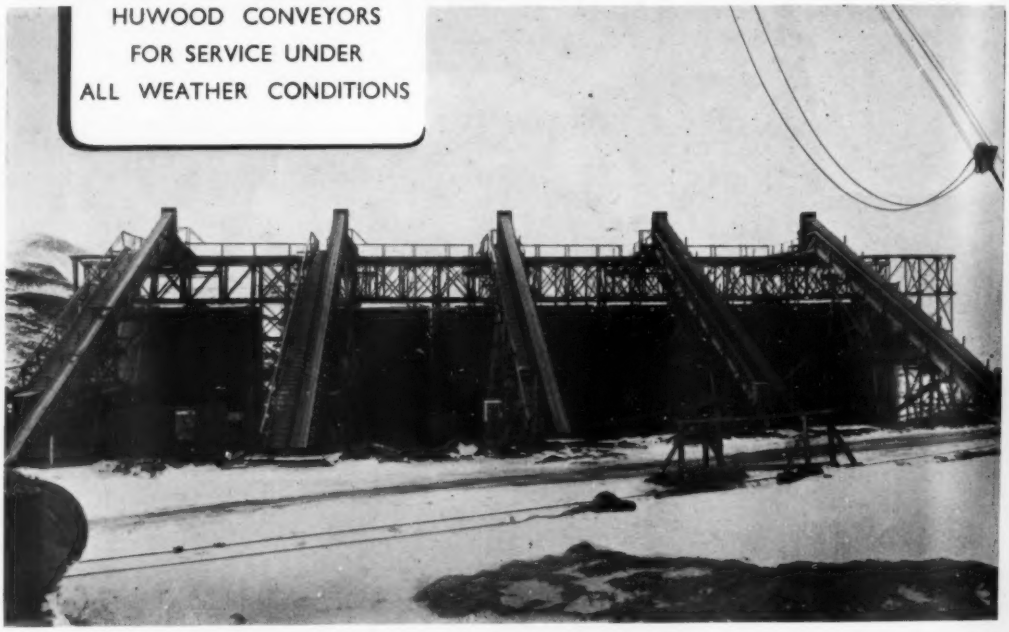

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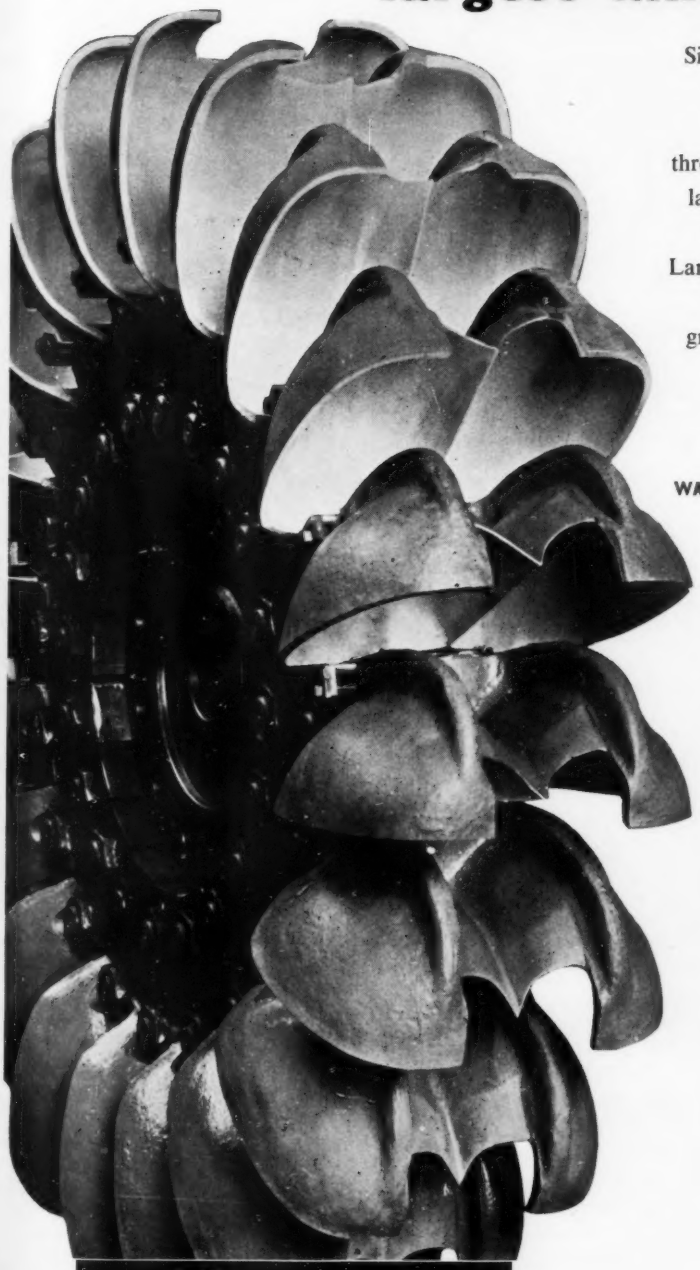
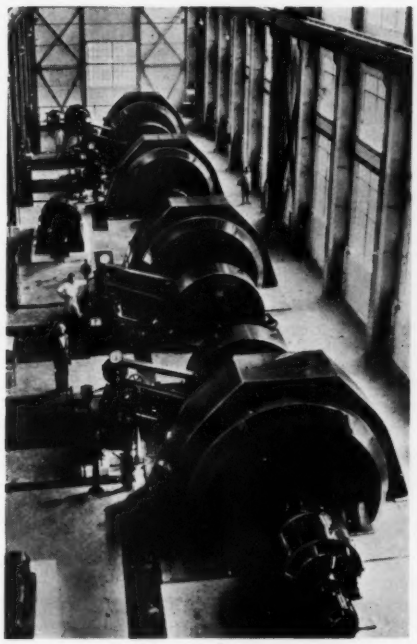


Since 1910 Boving have been manufacturing Pelton turbines and their wide experience on major hydro-electric schemes throughout the world coupled with intensive laboratory tests have enabled a continuous increase to be made in the size of units. Larger units mean fewer per station—lower maintenance—high efficiency, permitting great saving in overall capital cost. Nearly a million horsepower of Boving British built Pelton turbines are in operation throughout the world.

WATER TURBINES · PULP & PAPER MACHINERY, ETC.



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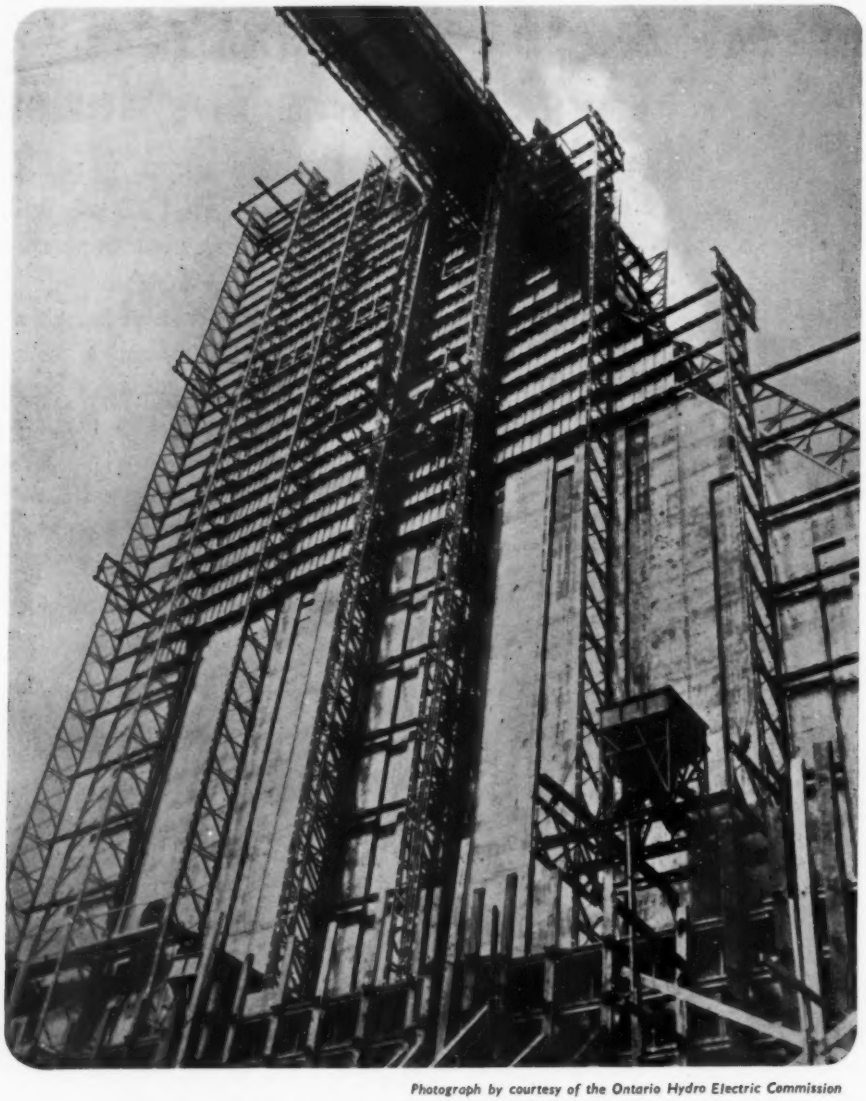

Photograph by courtesy of the Ontario Hydro Electric Commission

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Engineers throughout the world, engaged on major projects to harness natural resources, combine the structural and mechanical aids of Bailey Bridging with their technical and productive skill. To-day's tremendous speed of construction demands Bailey Bridging equipment which fulfils all requirements, regardless of magnitude. Our organization is privileged to place at your disposal a world-wide technical and Bailey Bridging supply service, unique in Civil Engineering.

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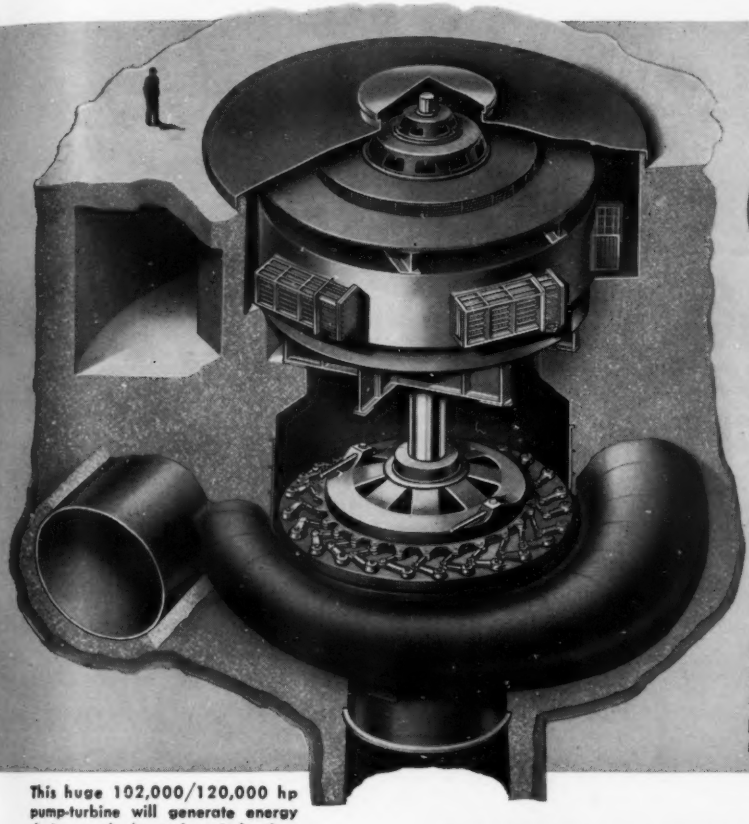
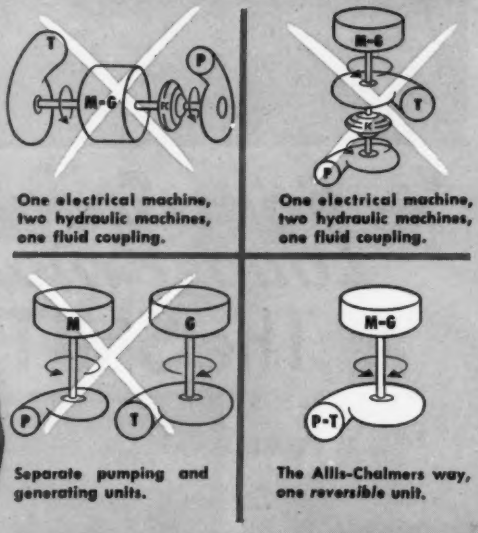
ALLIS-CHALMERS Pioneers *REVERSIBLE* Pump-Turbines!



This huge 102,000/120,000 hp pump-turbine will generate energy during peak demand periods, then reverse and — using surplus power from other plants — restore water to the reservoir during off-peak periods. Power value differential will make operation economical.

HOW REVERSIBLE PUMP-TURBINE REDUCES EQUIPMENT NEED



Sketches above show different methods of applying motive and generating equipment for pumped storage. Note that the Allis-Chalmers reversible pump-turbine at lower right requires least equipment and simplest power plant construction.

NOW BUILDING 5 UNITS FOR PUMPED STORAGE

THIS RECORD SIZE pump-turbine is now under construction by Allis-Chalmers for the Hiwassee dam in North Carolina. It combines in one reversible, two-element unit an electrical machine rated 102,000 hp as the world's largest motor and a hydraulic machine with the world's largest Francis runner.

When operating at maximum head as a turbine, this reversible unit will develop 120,000 hp. As a pump, it will move a maximum of 5200 cfs, 3.3 billion gallons per day . . . three times the capacity of the largest existing pump.

Allis-Chalmers — builder of over 12 millions of installed hydraulic horsepower — pioneered the development of the reversible pump-turbine for pumped storage. A-C offers you undivided responsibility, being able to design and build *all* elements of an entire reversible pump-turbine unit.

Of the five reversible pump-turbines A-C is now building, the Hiwassee unit is the largest. First scheduled for service is the 12,650 hp unit for the Flatiron Power & Pumping plant in Colorado. Three 19,000 hp units for the Sao Paulo Light & Power Co., Ltd., Brazil are now being built at Canadian Allis-Chalmers, Ltd., Montreal.

You get the real design advances *first* from Allis-Chalmers. And dealing with A-C is convenient, too, with 95 sales offices and 65 distributors located in 53 countries. For your free copies of Reversible Pump-Turbine Bulletin 01R7784 and illustrated, 56-page Bulletin 02B7301 of world famous hydro plants, just call your nearest A-C distributor or write to Allis-Chalmers, Milwaukee 1, Wisconsin, U.S.A. A-4011

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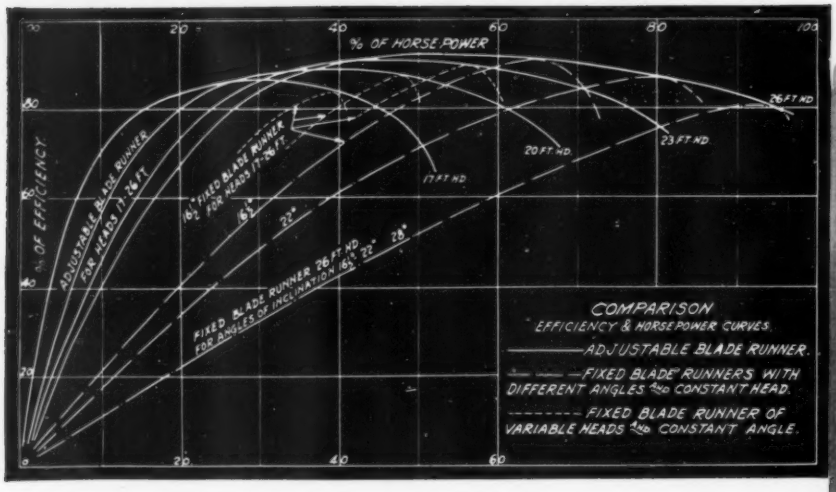
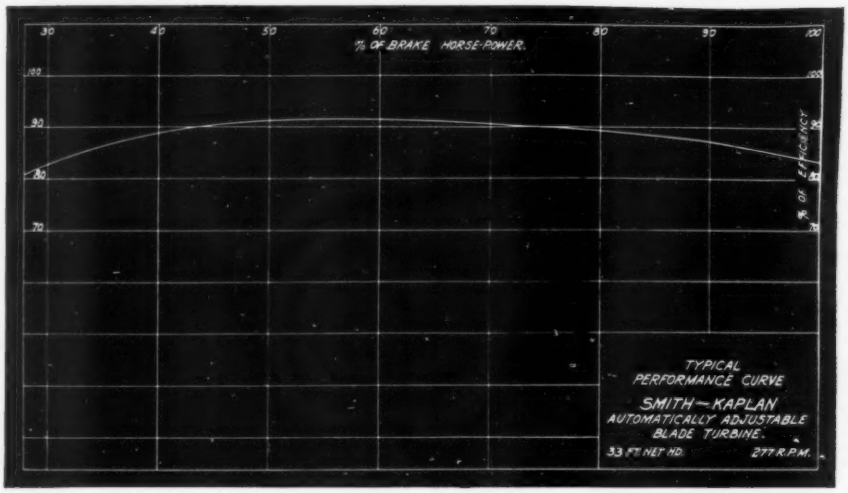

% OF HORSE POWER
% OF EFFICIENCY
ADJUSTABLE BLADE RUNNER FOR HEADS 17-26 FT.
FIXED BLADE RUNNER FOR HEADS 17-26 FT.
16½° 19° 22°
FIXED BLADE RUNNER 26 FT. HD. FOR ANGLES OF INCLINATION 16½° 22° 28°
17 FT. HD.
20 FT. HD.
23 FT. HD.
26 FT. HD.
COMPARISON
EFFICIENCY & HORSE POWER CURVES.
ADJUSTABLE BLADE RUNNER.
FIXED BLADE RUNNERS WITH DIFFERENT ANGLES & CONSTANT HEAD.
FIXED BLADE RUNNER OF VARIABLE HEADS & CONSTANT ANGLE.

"Actions Speak Louder than Words"

The SMITH-KAPLAN Turbine

If It's Hydraulics— Put It Up to Us!



EXAMINE the Charts, closely. Note performance!

The most marked advantages of the Smith-Kaplan Turbine are its ability to maintain high efficiency over a wide range of load, and to provide a high output under reduced head conditions. And these superiorities are even more pronounced when considered with its high specific speed which allows use of higher speed generators, resulting in marked economy of overall installation and lower costs of smaller power house! Send for Bulletin.

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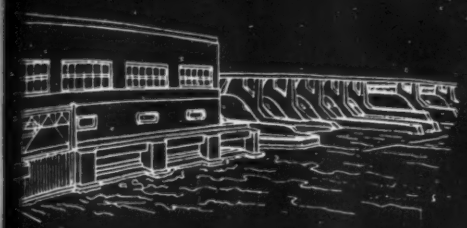
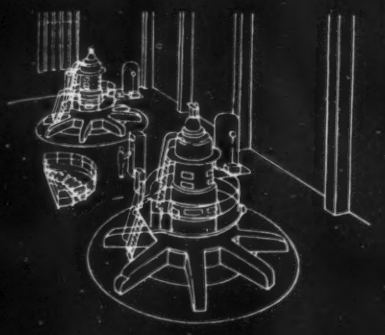
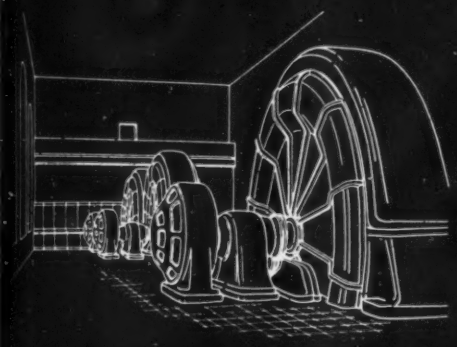
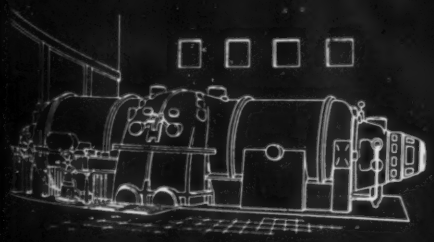
POWER by SMITH









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—continuously operating regulators with no moving parts and requiring no maintenance—have been in production since 1945 and, today, the regulators in service and on order control a total rating of

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serving machines up to 105,000 kVA.

Electro Hydraulic Turbine Regulators

enable all regulating operations to be electrically controlled while the actual regulation is carried out by hydraulic servo-motors.

Since 1945 ASEA has delivered, or has on order regulators for a combined turbine output of more than

3,000,000 h.p.

These equipments are made in collaboration with the Swedish turbine manufacturers NOHAB, Finshyttan and KMW.

•

Get in touch with us
We will gladly give you further details

ASEA

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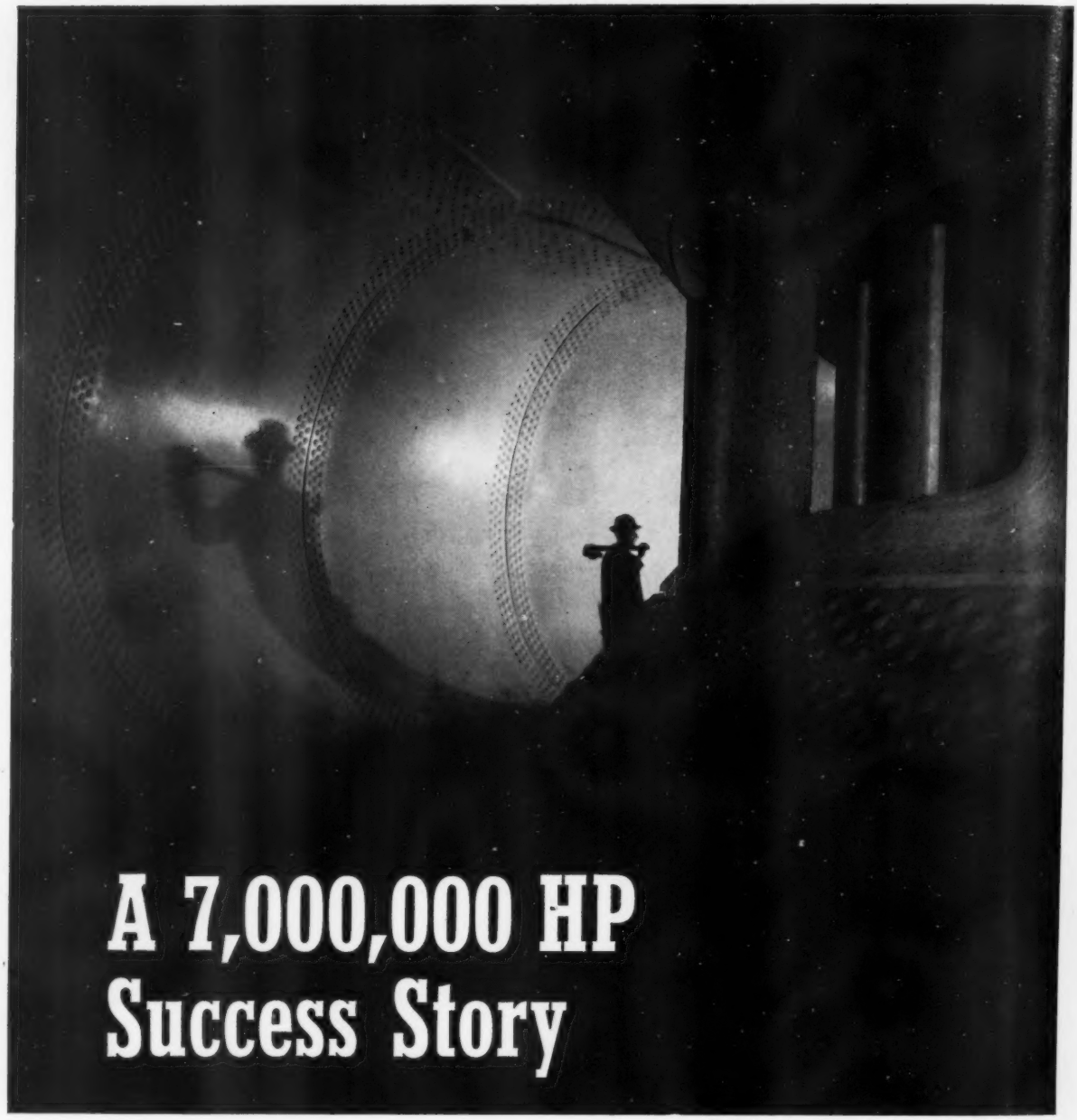


A 7,000,000 HP Success Story

Interior view of spiral casing at Norris Dam

Achievements of Newport News personnel in designing and building water power equipment during the past thirty years reflect a high integration of skill and production facilities.

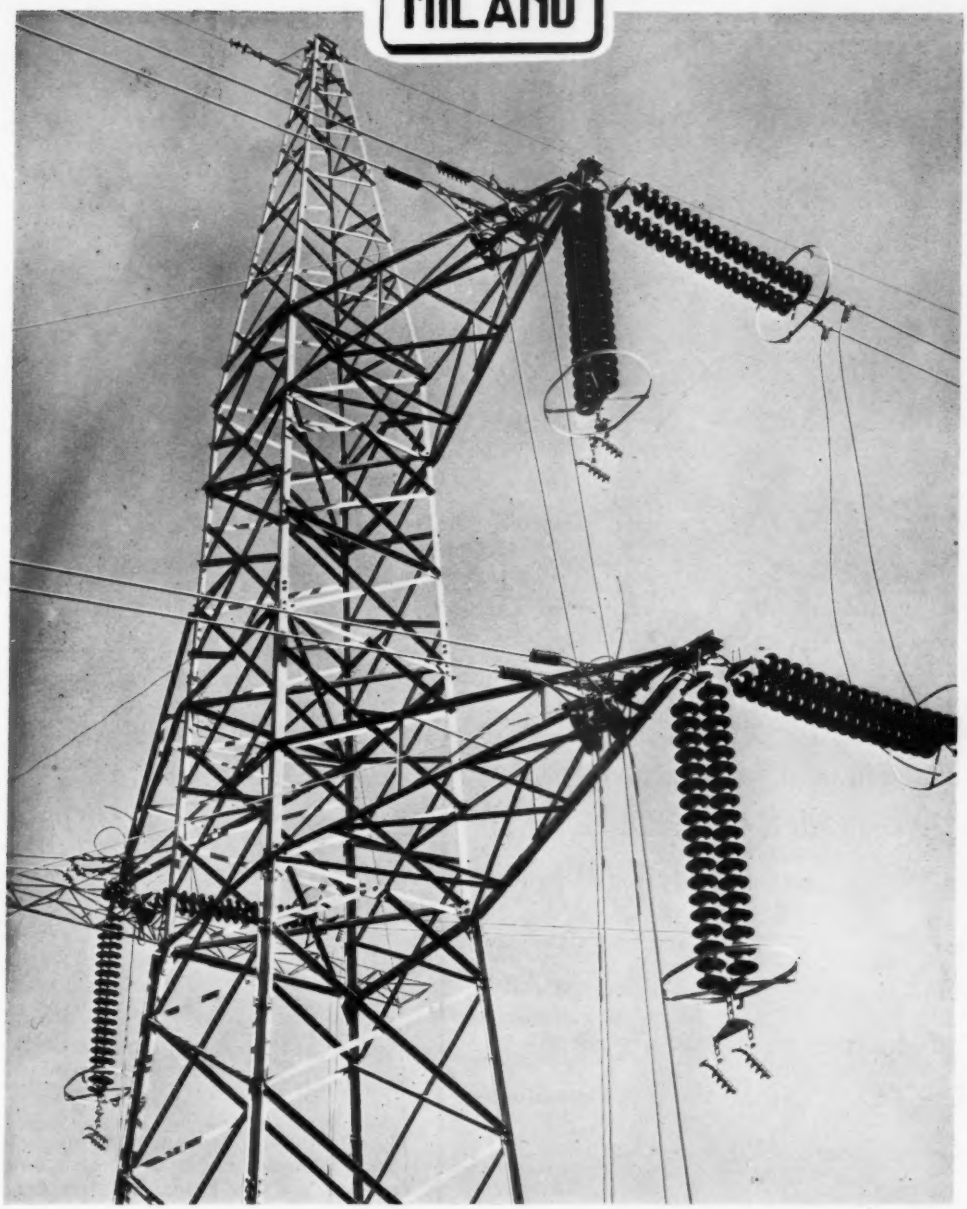
Answering demands for hydraulic turbines rated as high as 165,000 horsepower and as low as 500 horsepower, this trained organization has successfully filled contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Other essential equipment including penstocks, spiral casings, valves, pumps, gates and rack rakes are also designed and built by Newport News.

An illustrated copy of our booklet entitled, "WATER POWER EQUIPMENT," will be sent to you upon request.

NEWPORT NEWS **SHIPBUILDING AND DRY DOCK COMPANY**
Newport News, Virginia

HIGH VOLTAGE SALVI IFI MILANO LINE FITTINGS



3-230 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. Suspension and Strain Clamps. Arcing Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including pressures of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

We shall be glad to receive enquiries and to provide a data sheet indicating the details we require to enable us to quote for your requirements.

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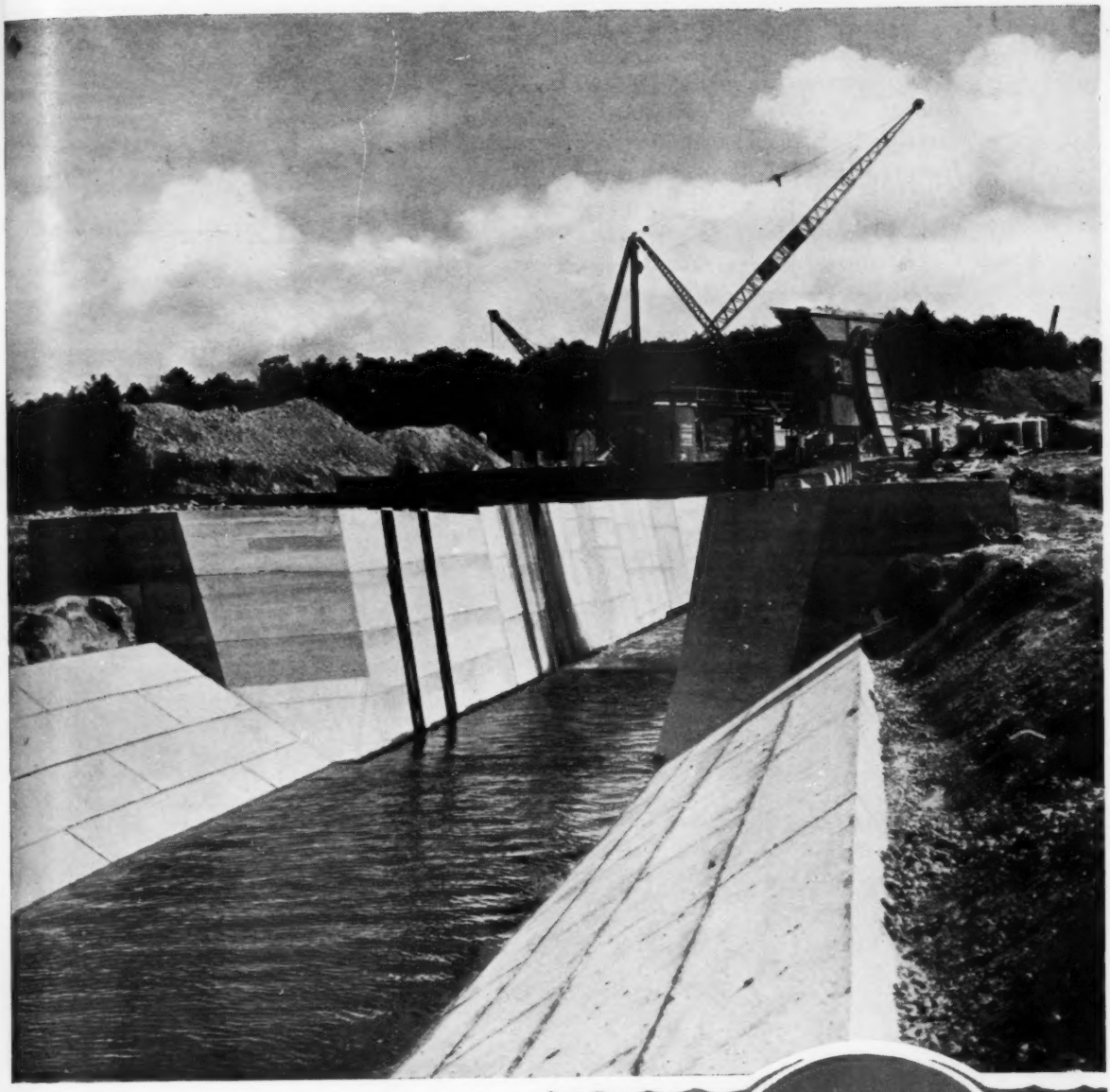

Work on the diversion tunnel and channel at the Weir Wood Reservoir Contract, which is one of the water conservation schemes being carried out by the Company

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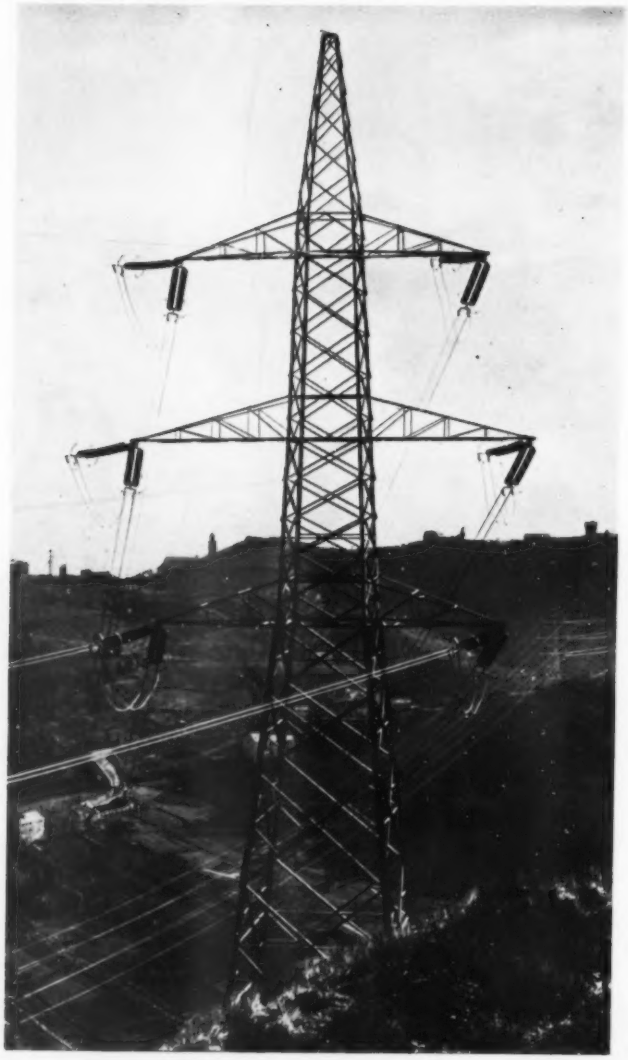
Erection equipment



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This 230 kV transmission line, built to feed the new Iron and Steel Works at Cornigliano in Italy, is designed to carry six twin 300 sq. mm. (.257 sq. ins. C.E.) S.C.A. conductors across very rough country with ice loadings up to 8 kg/m (5,4 lb/ft).

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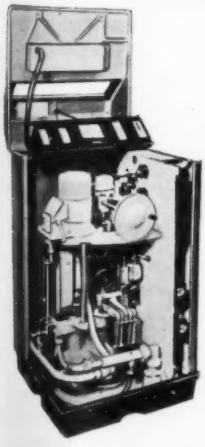

In the Kilforsen Power Plant, owned by The Royal Swedish Board of Waterfalls, we have installed an actuator controlling an output of about 90 M.W. in one unit. Two further actuators are under erection in the same power station.

In collaboration with ASEA we are supplying a number of plants in Sweden and abroad with complete electrical regulating equipment

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STORR LOCHS HYDRO-ELECTRIC SCHEME ISLE OF SKYE

Looking down the pipeline to the power station on the shores of Bearreraig Bay.

Interior of the power station showing one of the two 1,150 B.H.P. GILKES Francis Turbines.

This installation is one of the North of Scotland Hydro-Electric Board's smaller stations, supplying the Isle of Skye and the adjacent mainland. A dam has been constructed impounding Loch Leathan and Loch Fada, making them into a single storage reservoir. From this, a 42 inch diameter pipeline 2,700 feet long leads to the power station almost at sea level.

The station contains two 1,150 B.H.P. 1,000 r.p.m. GILKES Francis Turbines operating on a net head of 435 feet and driving 800 kW alternators. Provision is made for the installation of a third unit.

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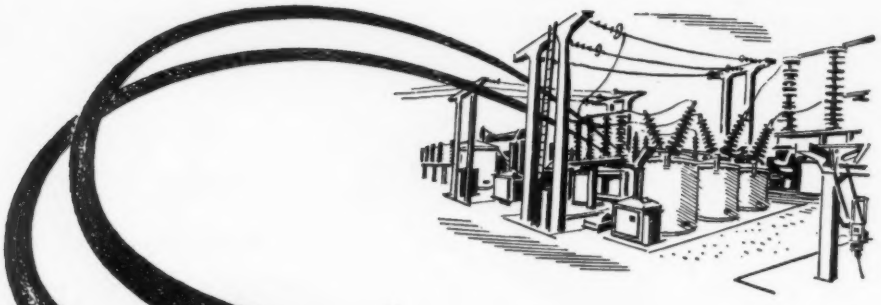
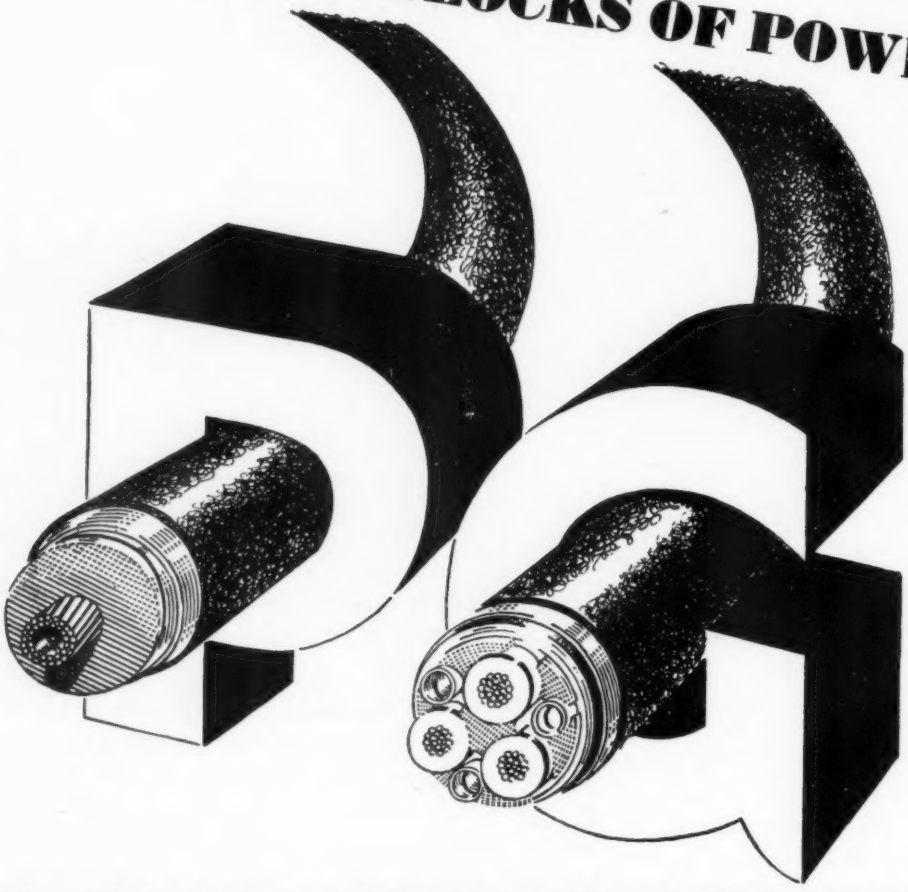


FOR LARGE BLOCKS OF POWER



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33 kV to 330 kV

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PIRELLI GENERAL CABLE WORKS LIMITED SOUTHAMPTON
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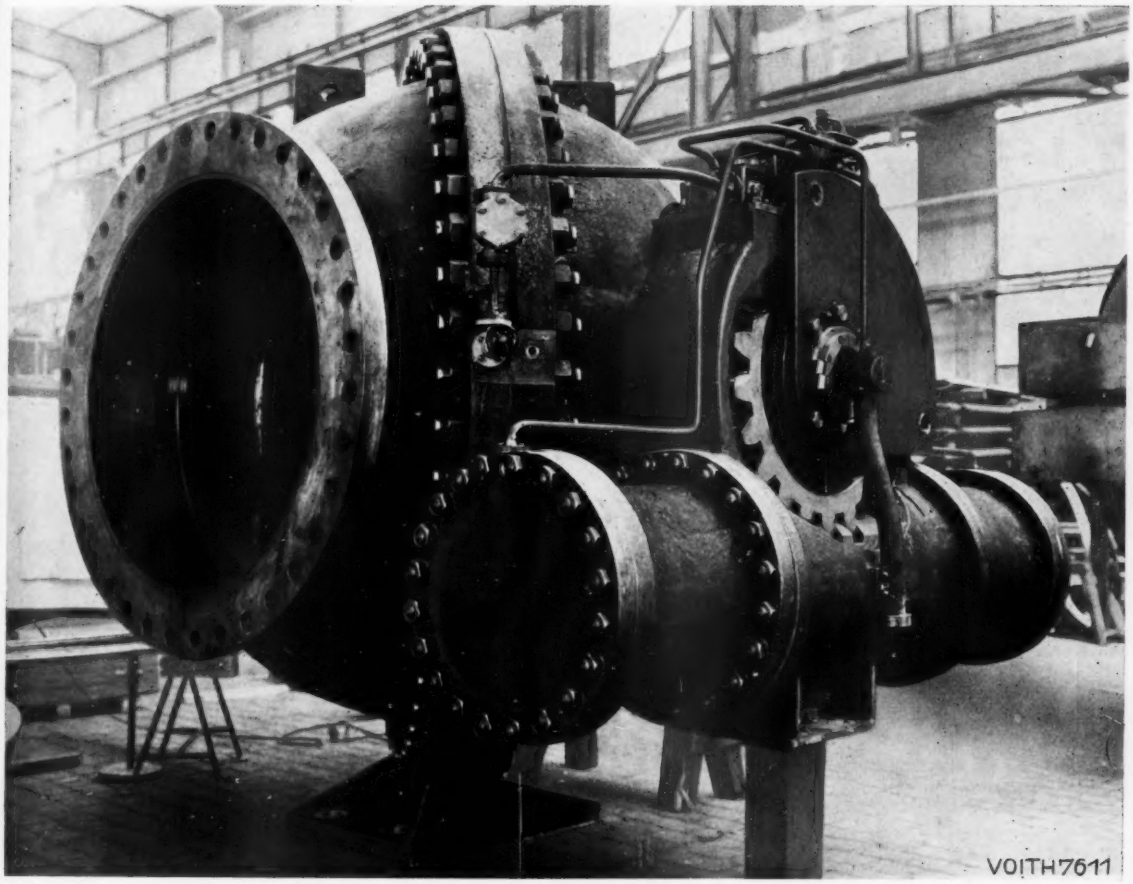
Voith Penstock Shut-Off Valves



Workshop assembly of a spherical valve, inside diameter 1500 mm., with hydraulic drive. The casing of the spherical valve is diagonally split.

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Spherical Valves inside diameters up to 2,200 m.m., maximum water pressures up to 1,010 m.

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Butterfly Valves inside diameters up to 5,300 mm., maximum water pressures up to 270 m.

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)
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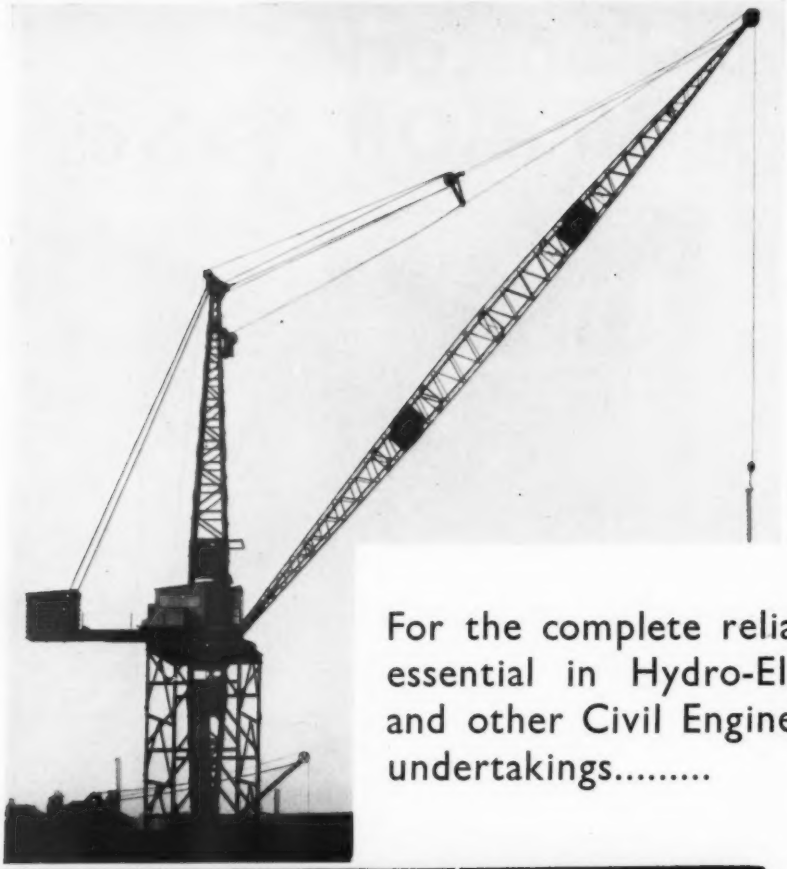

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In over 80 years of specialised experience of crane building we have been privileged to supply cranes to many of the greatest hydro-electric and other civil engineering contracts ever undertaken, and have developed a considerable knowledge of operating conditions to be expected in most parts of the world. We are always happy to co-operate with engineers in deciding the most suitable types and sizes of cranes for any purpose and shall be pleased to submit designs and quotations on request.

The illustrations show a monotower (top) and a derrick crane, types which have had great success in Hydro-Electric developments and which we make in a variety of sizes and powers.

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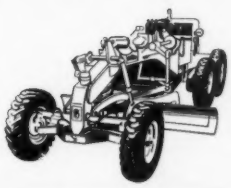

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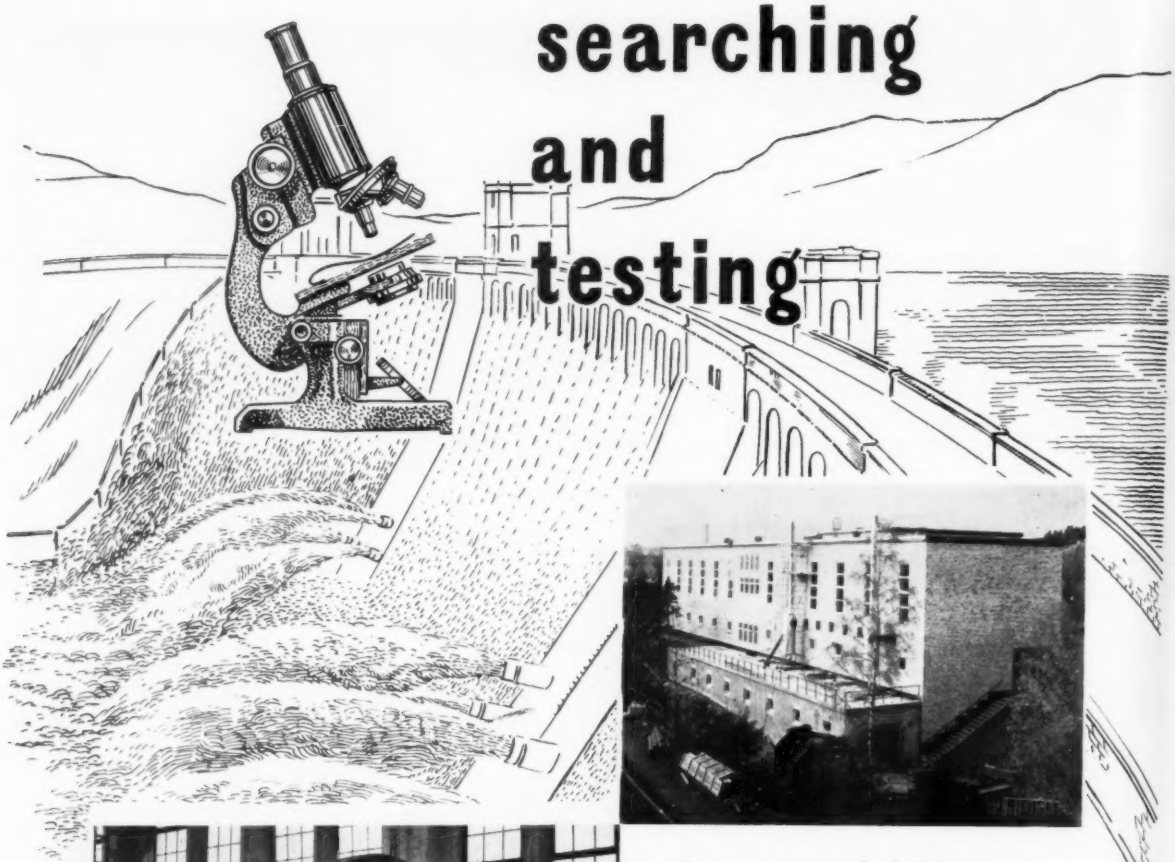

Our new research building at TROLLHÄTTAN has a water turbine laboratory containing a cavitation test stand, low-head and pump units and an aero-dynamic testing device. Also at TROLLHÄTTAN is our modern turbine testing station which harnesses power from the Göta river to test model runners of 600 mm. diameter.

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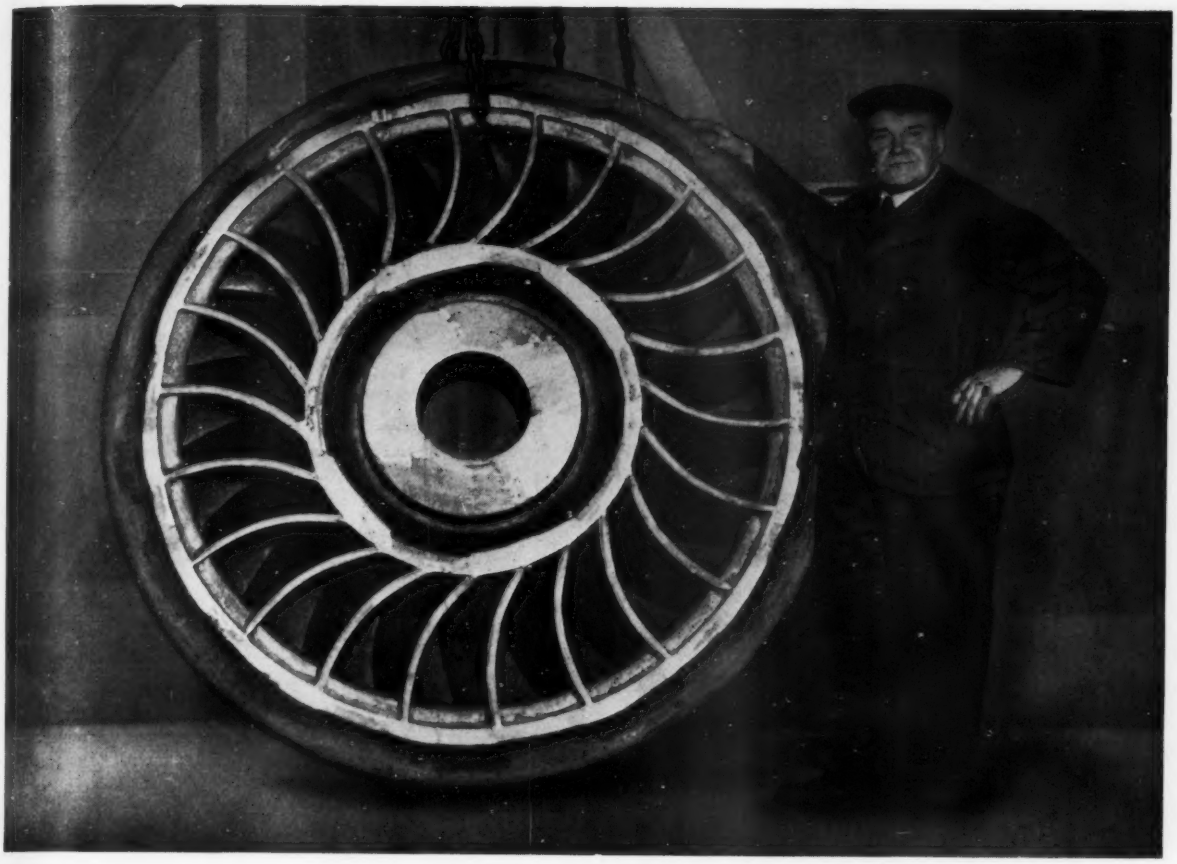

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3 ARGHANDAB DAM, Kingdom of Afghanistan. Completed in 1952. 1804 ft. long; 167 ft. high. Arghandab is another step in the Kingdom's long-range development program.

4 KENNEY DAM, British Columbia.* Completed November, 1952. 1600 ft. long; 295 ft. high. Kenney Dam is a unit in the Nechako-Kitimat project being built for the Aluminum Company of Canada.

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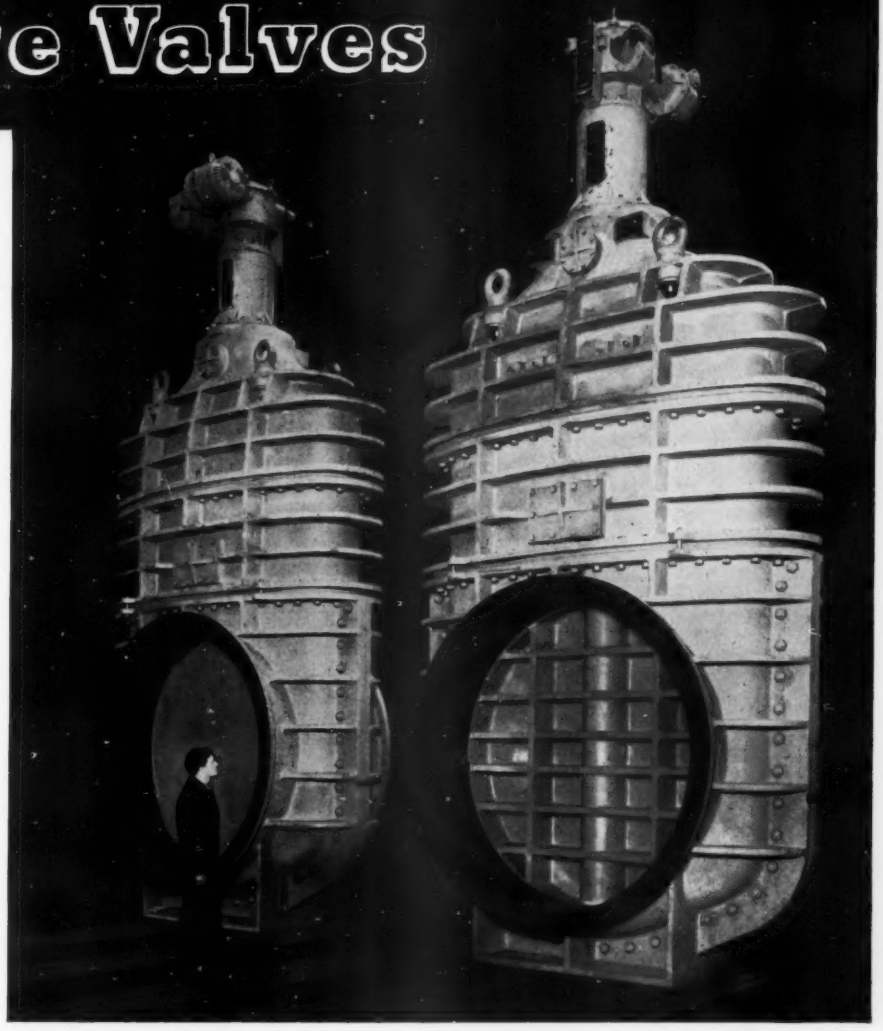

VALVES in the larger sizes call for their own special treatment, and few firms have anything approaching Blakeborough experience in this field. We were manufacturing valves up to 66″ diameter nearly 60 years ago, and since then have built up facilities for the production of this class of equipment on an exceptional scale. Sluice valves are available from existing patterns in a full range of sizes up to 96″ diameter; needle valves in any required size; penstocks up to the largest in use; etc. Power driven operating gear is arranged to suit requirements.

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North of Scotland Hydro-electric Scheme

The supply and erection of some ninety miles of 132kV overhead transmission lines, over the wild and rugged Highlands, was recently entrusted to Henley's Contract Department by the North of Scotland Hydro-Electric Board.

Illustration. Hillside view of HENLEY 132kV single circuit towers overlooking Loch Luichart. (Note: The footings of one tower are above the peak of the other which is only 150 ft. distant.)

Consultants: Messrs. Kennedy and Donkin

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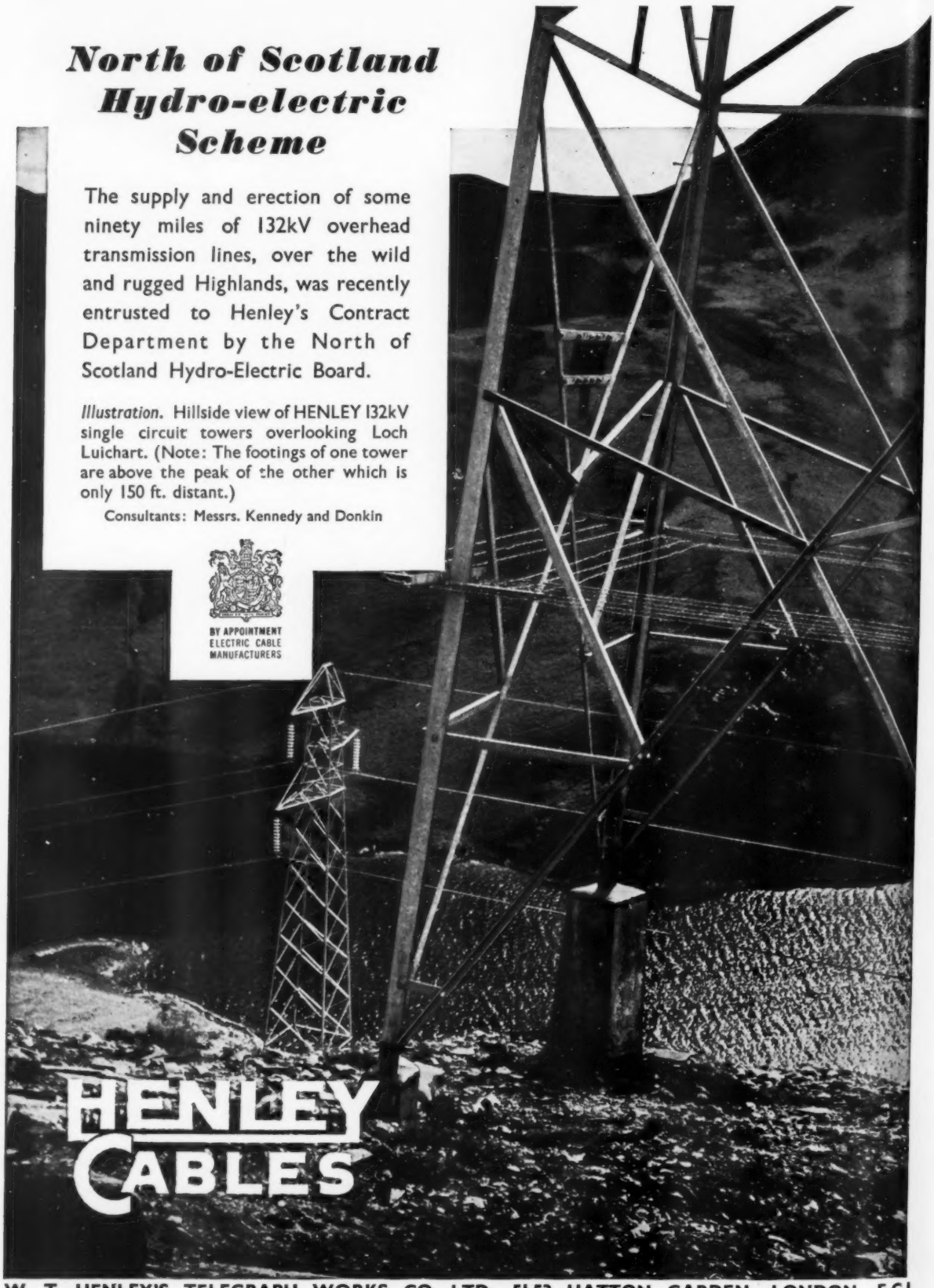

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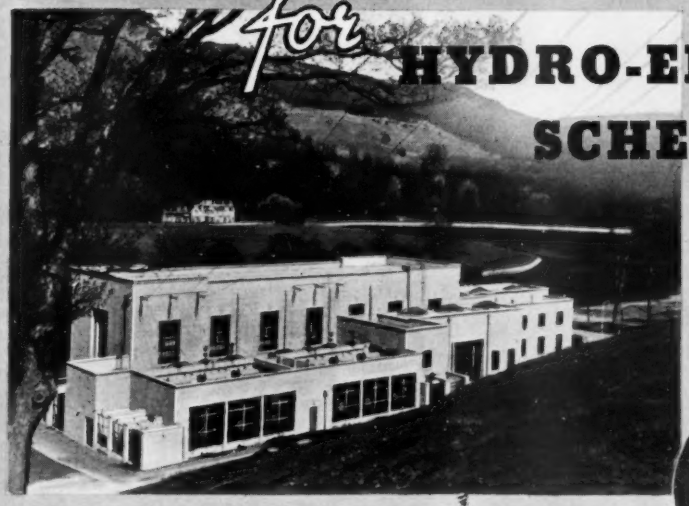
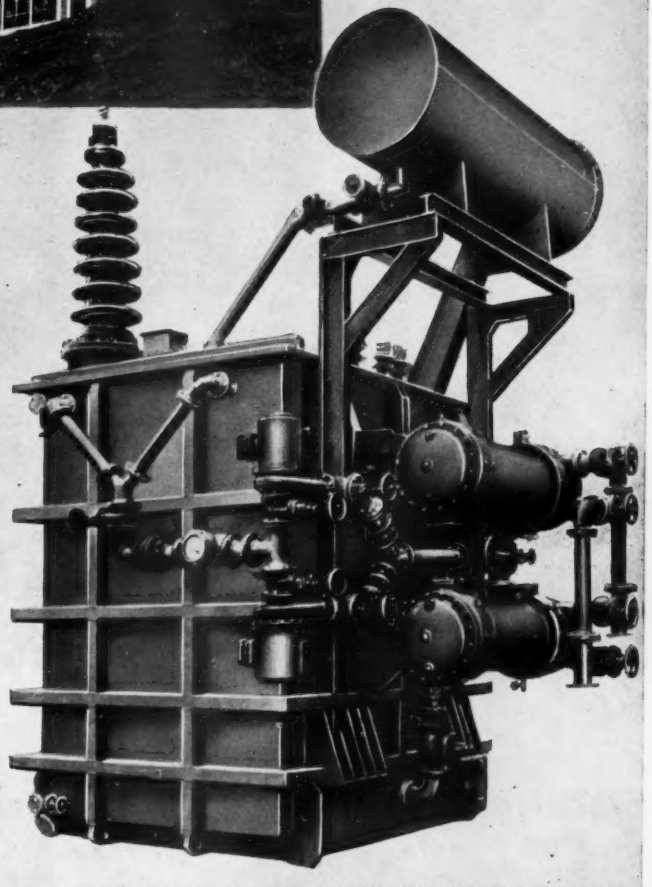


CLUNIE POWER STATION of the North of Scotland Hydro-Electric Board where 6-20,000 K.V.A. water-cooled transformers, as illustrated at right, operate in two 60,000 K.V.A. 11,000/132,000-volt three-phase banks. Also installed at this power station is a three-phase magnetically shielded reactor capable of dealing with a power fault of 400,000 K.V.A. at 11,000 volts.



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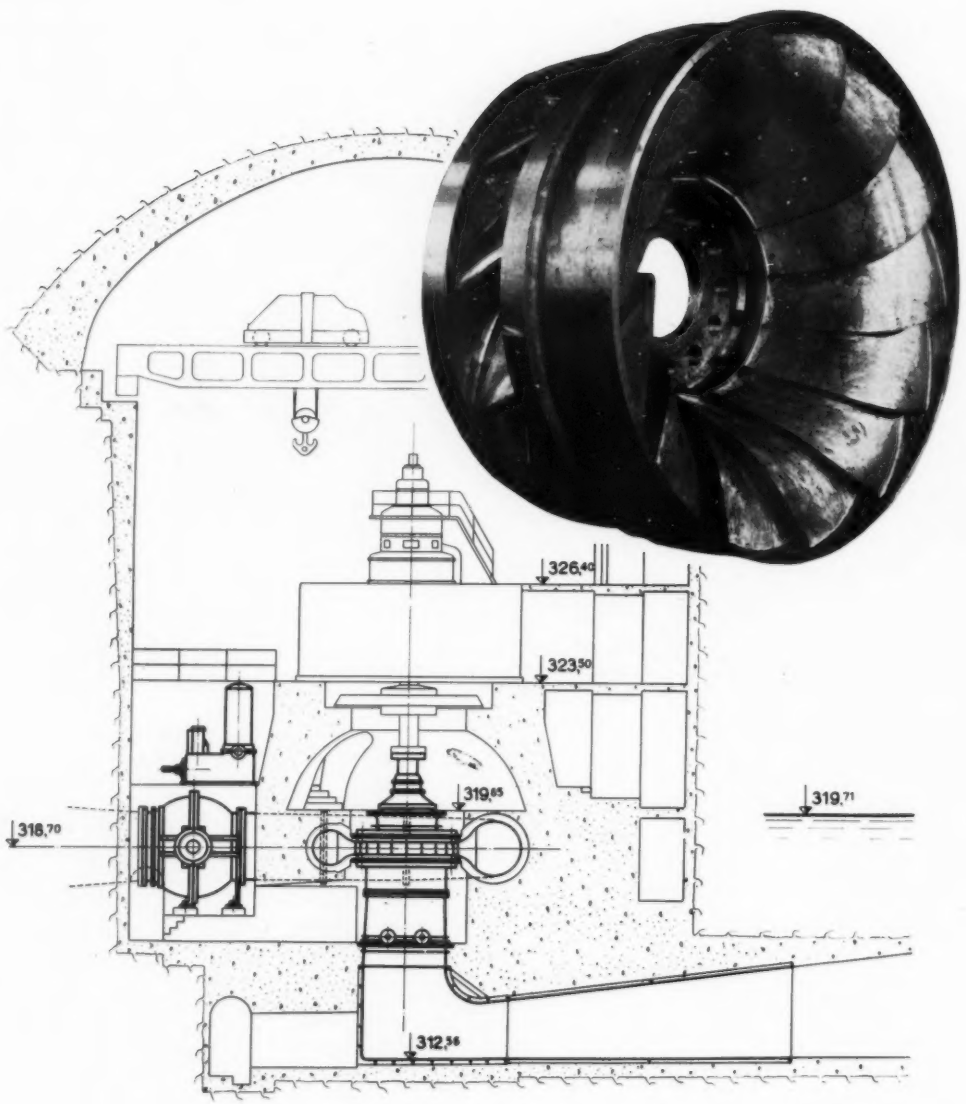

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Output : 48,000 h.p.
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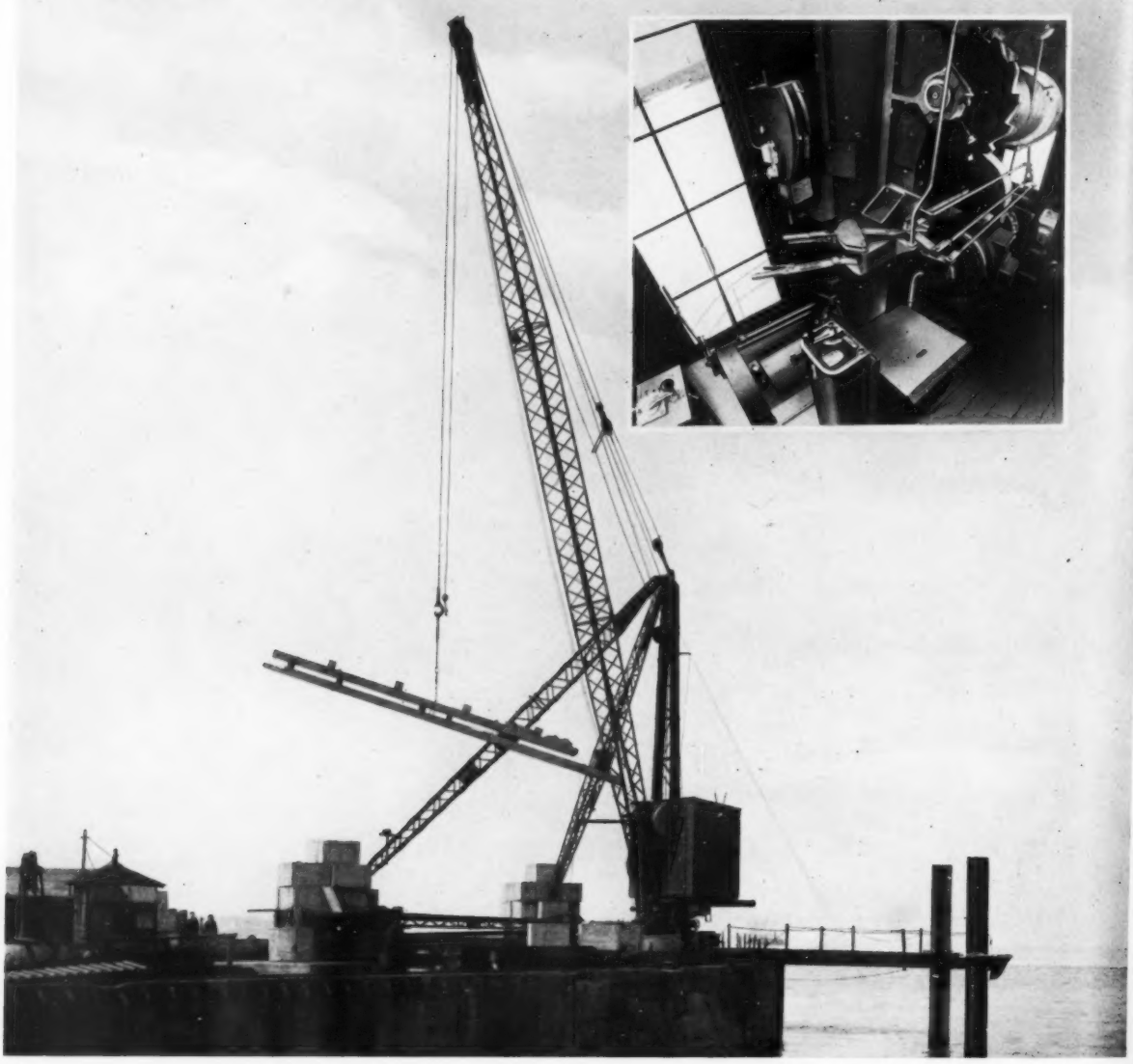

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One of three Henderson 10-ton, 2-motor, electrically-driven Derrick cranes with 120-ft. jibs, supplied to Mersey Docks and Harbour Board for use on the Langton Canada Improvement Scheme.

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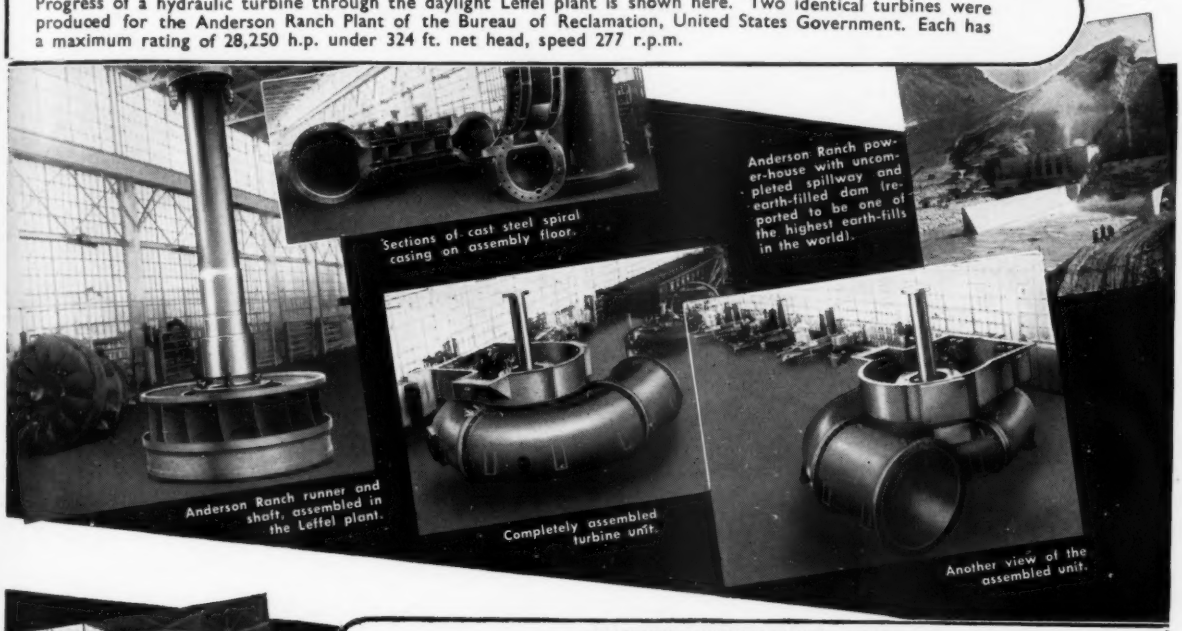
A TYPICAL EXAMPLE OF LEFFEL PRODUCTION

Progress of a hydraulic turbine through the daylight Leffel plant is shown here. Two identical turbines were produced for the Anderson Ranch Plant of the Bureau of Reclamation, United States Government. Each has a maximum rating of 28,250 h.p. under 324 ft. net head, speed 277 r.p.m.



Sections of cast steel spiral casing on assembly floor.

Anderson Ranch power-house with uncompleted spillway and earth-filled dam reported to be one of the highest earth-fills in the world).

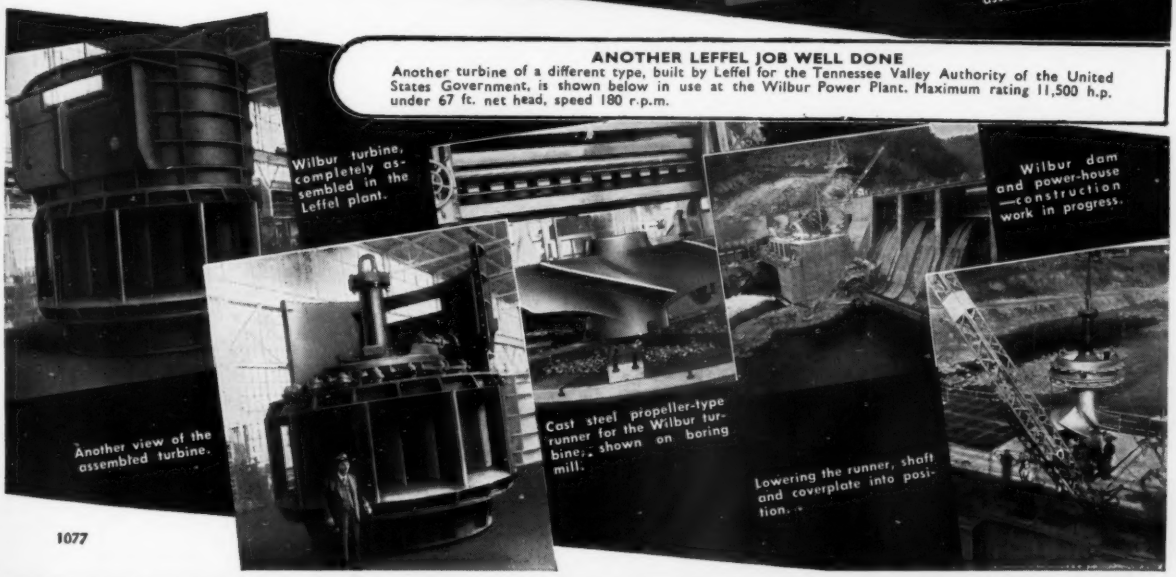
Anderson Ranch runner and shaft, assembled in the Leffel plant.

Completely assembled turbine unit.

Another view of the assembled unit.

ANOTHER LEFFEL JOB WELL DONE

Another turbine of a different type, built by Leffel for the Tennessee Valley Authority of the United States Government, is shown below in use at the Wilbur Power Plant. Maximum rating 11,500 h.p. under 67 ft. net head, speed 180 r.p.m.



Wilbur turbine, completely assembled in the Leffel plant.

Another view of the assembled turbine.

Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.

Lowering the runner, shaft and coverplate into position.

Wilbur dam and power-house—construction work in progress.

1077

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66 MW at 132 kV at FASNAKYLE

all TURBINES GENERATORS METERING and SWITCHGEAR

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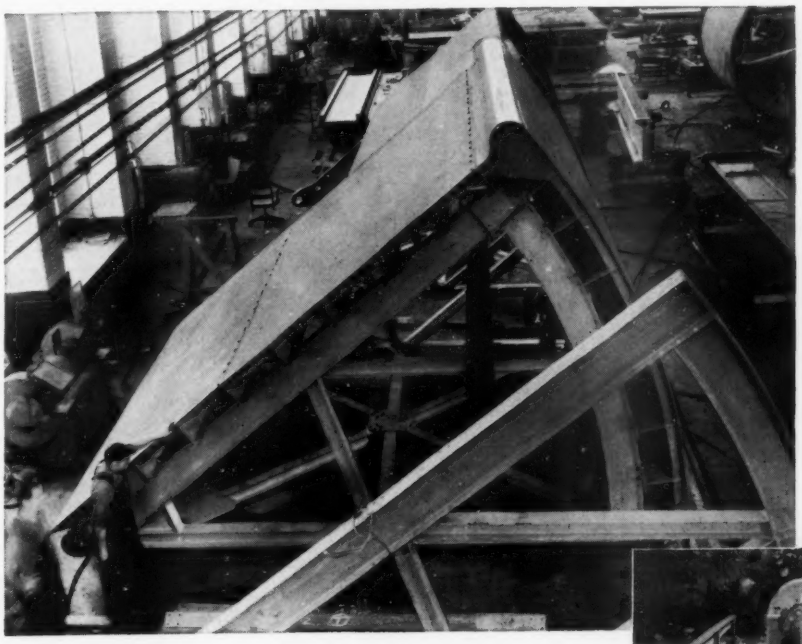
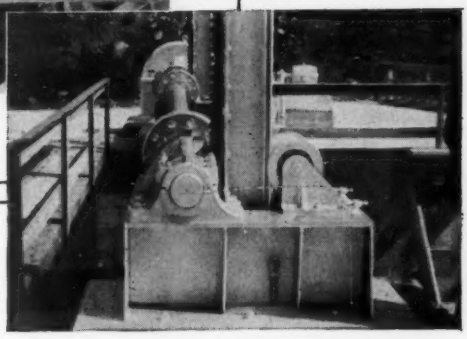
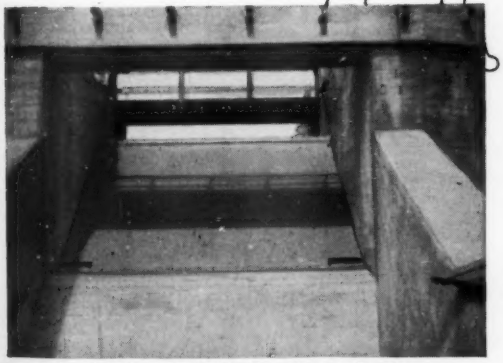


Shop photo of Taintor Gate during fabrication.



Partial view of operating mechanism.



Taintor Gate in position, looking up-stream from log-chute.

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In constructing most Canadian Power Dams, provision must be made for the free movement of logs. The idea of using Taintor Gates to admit water to the log chute was conceived by the Hydro Electric Power Commission of Ontario . . . the Gate and all operating mechanism was designed and fabricated by Canadian Vickers. Thus imagination plus engineering know-how achieved a new and totally satisfactory answer to an old problem.

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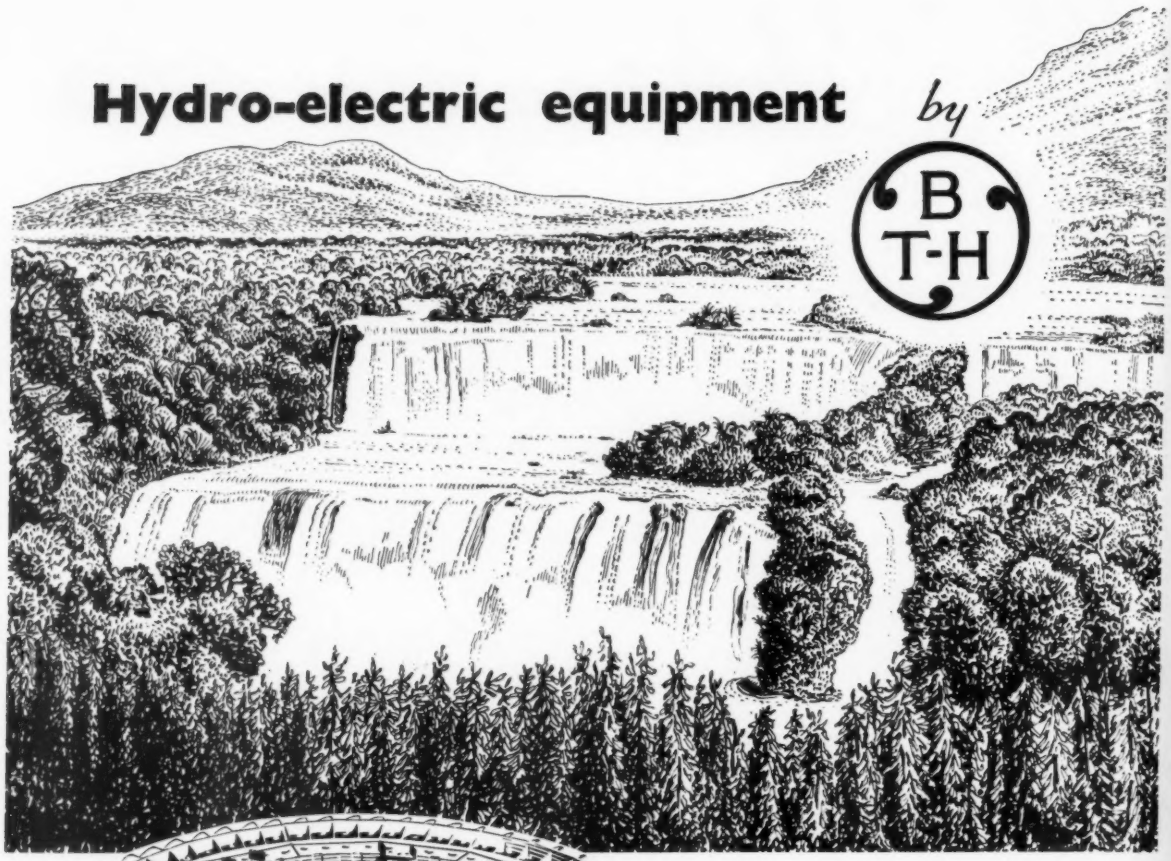

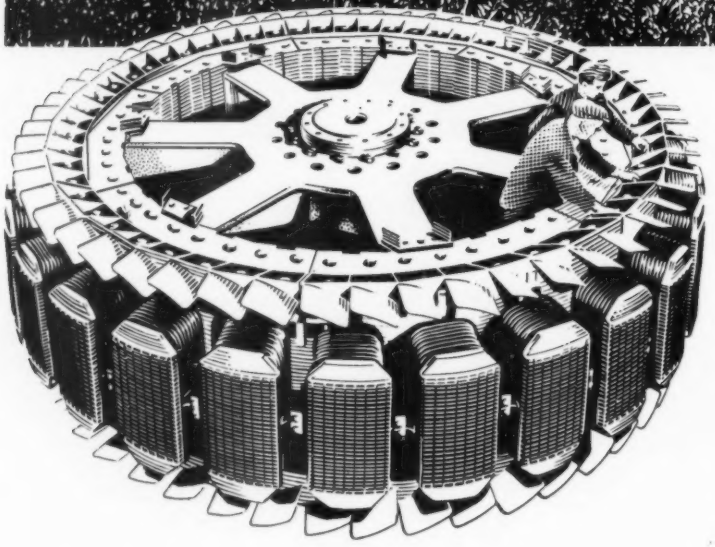

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A natural source of perpetual power lies in the upland lakes and rivers of almost all countries. To harness it, BTH supply all plant required for hydro - electric power schemes. The long experience of hydro-electric engineering possessed by BTH is one reason for the superiority of their equipment. Another is the exceptional capacity of the Rugby works, where plant on a very large scale, such as is required for many hydro-electric schemes, can be built and assembled without restriction.

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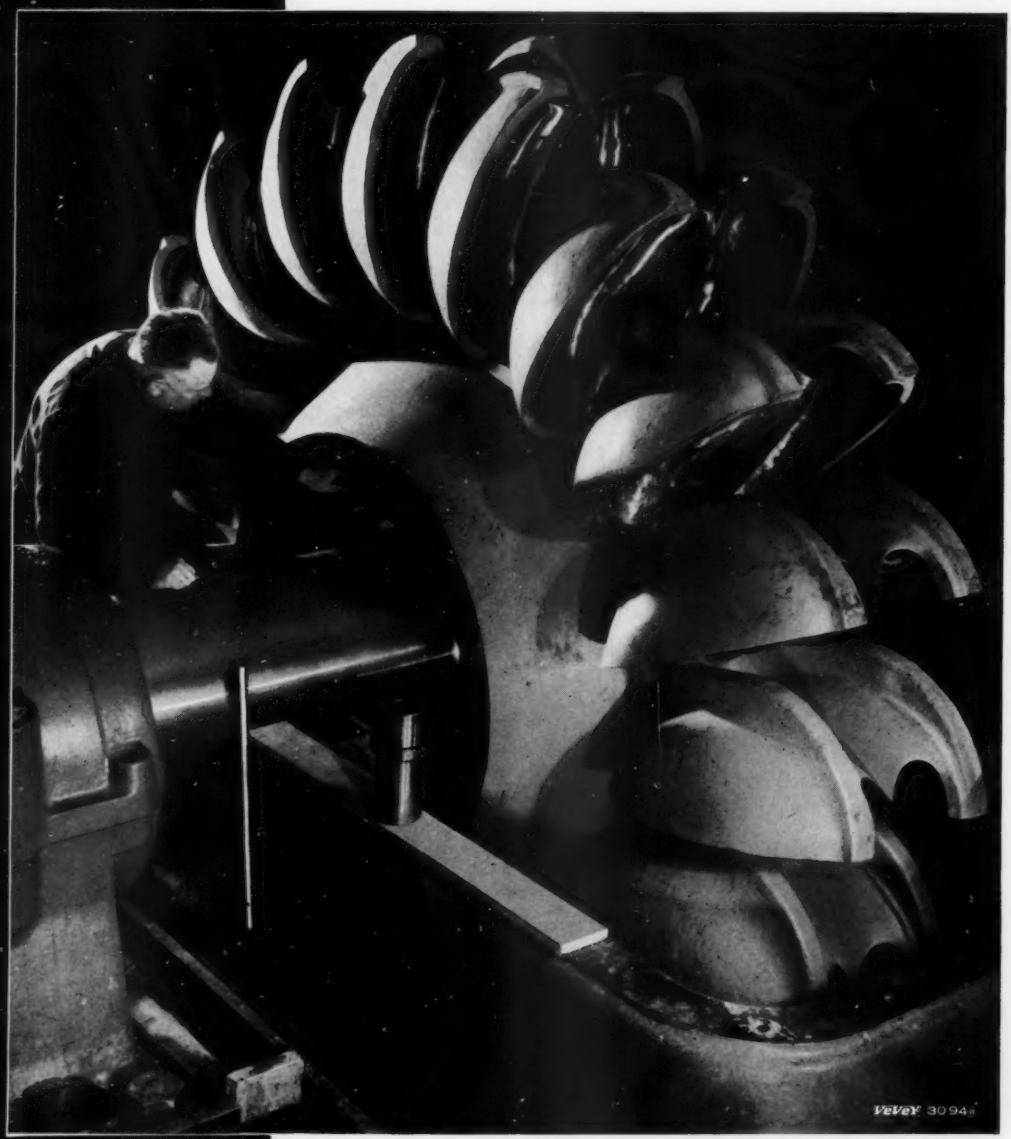

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Complet Equipment for Hydro-electric Power Plants

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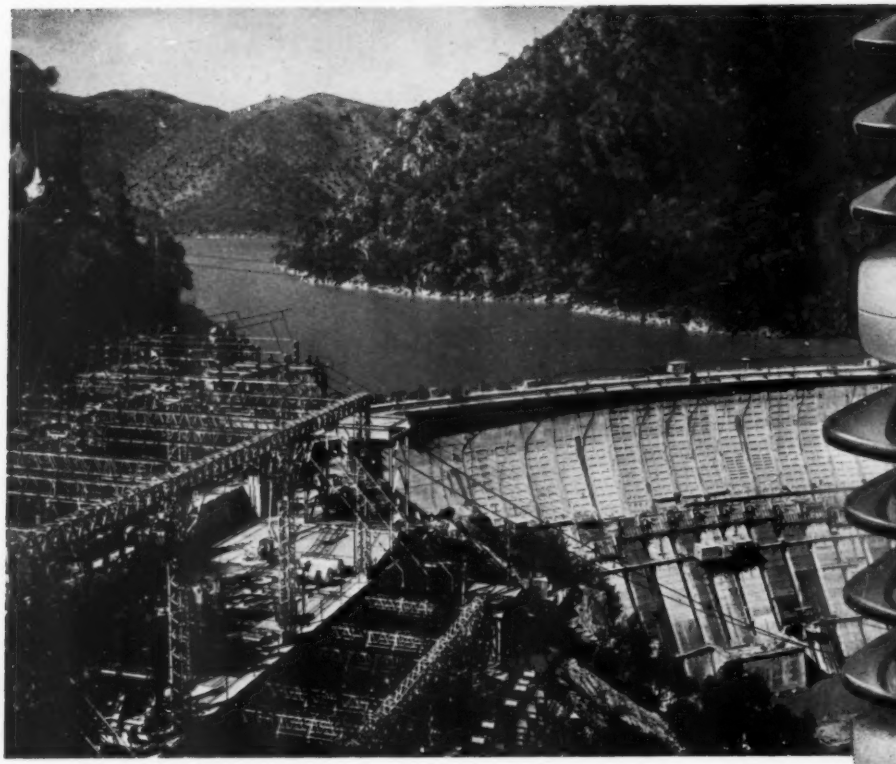
S.P.P. Post Insulators were specified by the New South Wales Public Works Department for Burrinjuck Sub-Station.



The Burrinjuck 132 kV Switching Station was equipped with Cylindrical Post Insulators type P.703. This is one of many stations on the New South Wales Public Works Department system equipped throughout with S.P.P. Post Insulators for 110 kV and 66 kV.

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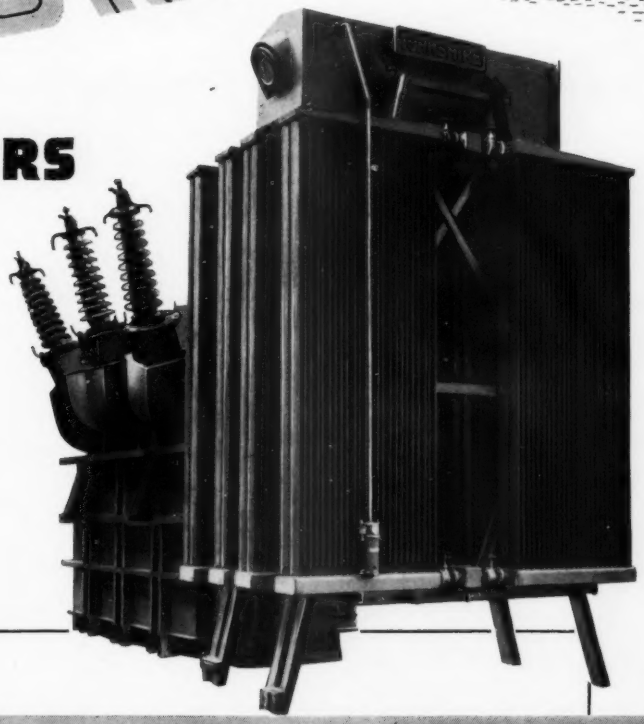

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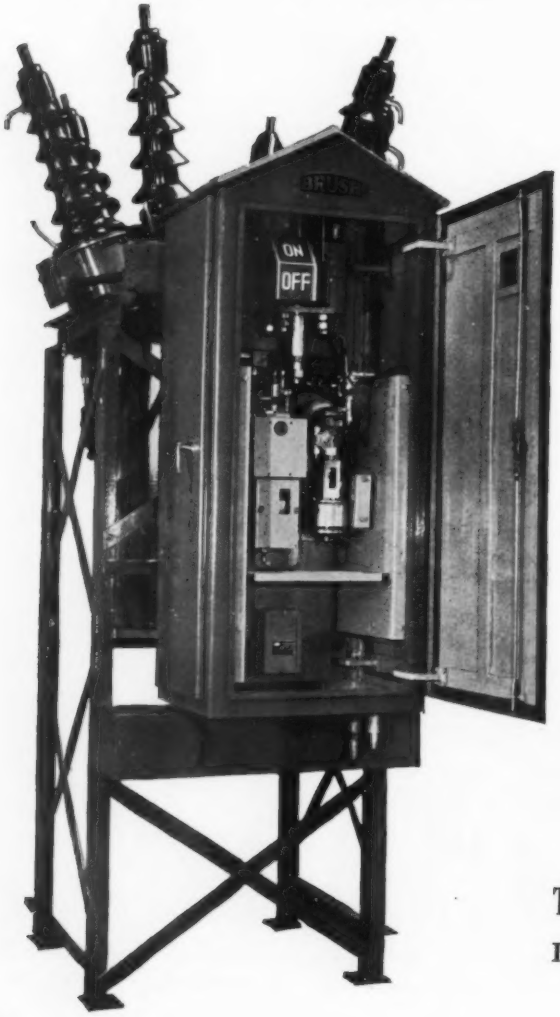
Built to comply with British Standard 116-1937 (Part 2) it has been subjected to short circuit test and certified for the rating assigned—i.e. 1,000 amps.—750 MVA Breaking Capacity—33 and 38.5 kV.

The illustration left shows a circuit breaker fitted with apparatus for pneumo-hydraulic operation. The circuit breaker may be closed four times in succession without recourse to auxiliary power supply.

As an alternative BRUSH Outdoor Circuit Breakers can be fitted with Solenoid Operating Mechanism.



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Oil Circuit Breakers

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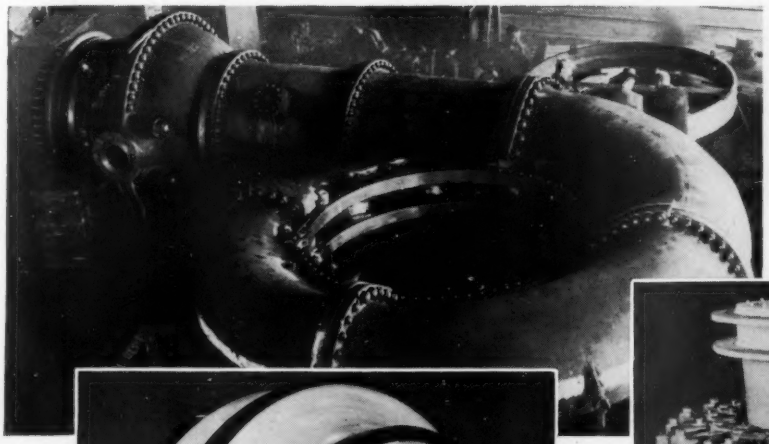
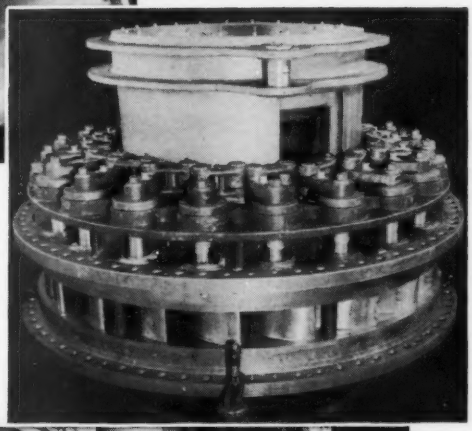
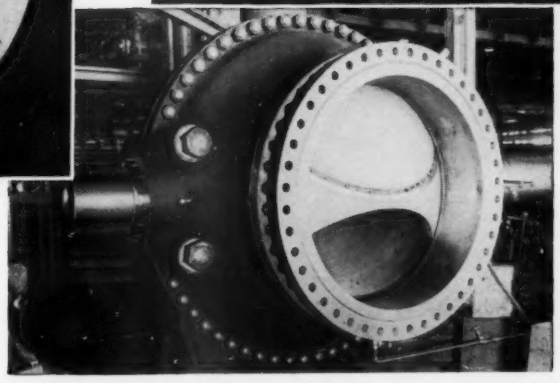
H.P. 62,000 — Head 875 ft. — Speed 450 RPM



A high head Francis turbine recently put into service in Canada, built by Dominion Engineering, manufacturers for over thirty years of the famous Dominion Turbines—Francis, Propeller and Impulse types—which are harnessing more than half the water power developed in Canada.





Top Left—Spherical Valve and Spiral case undergoing shop tests.

Left Centre—Stainless Steel Runner.

Right Centre—Turbine Gate Mechanism Assembly.

Bottom Right—56" Diameter Spherical Valve.

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DOMINION ENGINEERING

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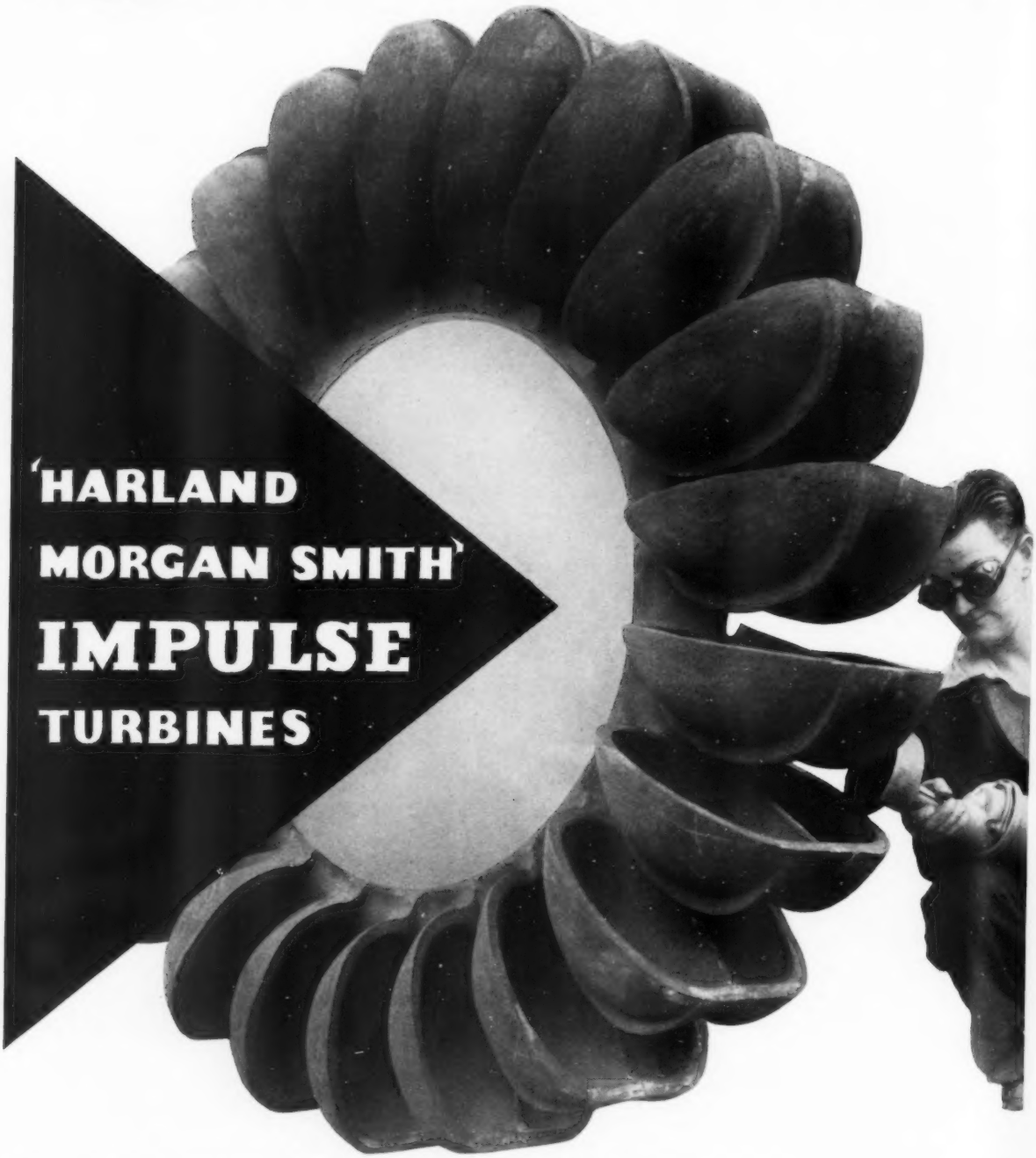
MONTREAL, CANADA

CABLE: DOMWORKS

HARLAND **HYDRO-ELECTRIC PLANT**



Commencing work on a 9,000 B.H.P. turbine for driving a 7,059 kVA "Harland" alternator.

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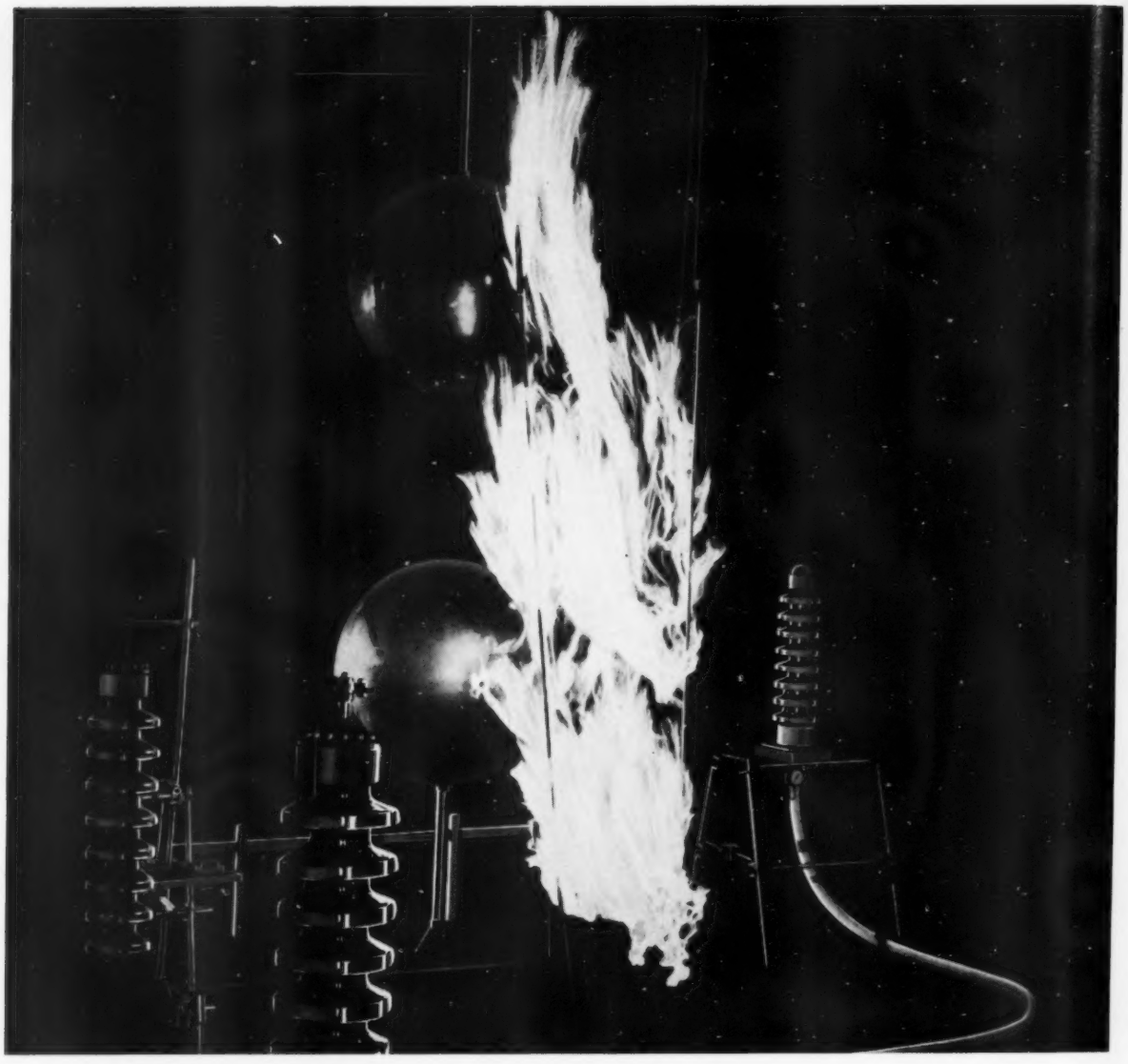

STORM before a Calm

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Labour Relations

THE Annual Reports of electricity-supply organisations, both state-controlled and private enterprise, become each year more informative, and contain an ever-growing volume of statistical data relating to almost every branch of the work of the body concerned, but there is one aspect on which all but a very few are officially silent. This is the matter of labour-relations machinery, which is ever becoming a more vital and onerous part of the task of management. The British Electricity Authority's Reports are almost unique in the world in containing a considerable section devoted to a review of the year's work in this field, and setting out the working of the organisation of negotiation and consultation, which extends throughout the Authority itself and the Area Electricity Boards who distribute the current it generates, to its 14 million consumers.

There is, however, ample news from other sources of progress, or the reverse, towards the perfection of labour-relation machinery in the organisations of other supply authorities throughout the world; and in reviewing the considerable volume of such information which we have available we cannot but attach significance to the fact that there are fewer labour disputes, and the necessity for elaborate machinery is much less, in those electricity-generation authorities where there is a preponderance of hydro-electric power.

The reason is not far to seek. First of all, any thermal power station needs to employ a large number of men who are occupied for the whole of their time on such drab tasks as fuel-handling, ash disposal, attention to pulverising mills, and the like. It is inevitable that once they have mastered the simple elements of the task in hand, they must devote their thoughts to other matters; and among these, the notion of remedying real or supposed grievances will inevitably rank high.

Again, the extremely complicated nature of a high-pressure steam installation means that maintenance is a factor which demands a considerable concentration of labour, both skilled and unskilled, but which nevertheless constitutes a force of men who are not regularly employed for the whole of the year. It is necessary for them to work very long hours, at overtime rates, either when a piece of apparatus is deliberately taken out of commission for maintenance purposes, or on those occasions when a breakdown necessitates emergency measures. Men employed under these conditions are liable to become a prey to dissatisfaction. A lengthy period of highly paid overtime, followed by a spell when overtime is not necessary and when day-to-day work is light, causes a considerable strain on human nature.

On the other hand, the hydro-electric station, unless it contains some very special features, needs in any case far fewer men for its normal operation than applies to a steam station of equivalent capacity. Breakdowns are fewer, and maintenance is often carried out on an annual schedule involving a number of stations, with the skilled maintenance gang working their way from plant to plant, and always being fully employed. The minimum number of men are engaged in non-creative work. And there is about hydro-electric plant an underlying air of appreciation of the fact that natural resources are being used in a manner which is altogether efficient and is not overcast by the tantalising failure, inherent in the steam cycle, of being able only to utilise less than one-third of the costly and dangerously won fuel which is used in such vast quantities and which is in any case irreplaceable.

It is of course true that hardship is sometimes associated with work in hydro-electric stations, particularly those in the more northerly latitudes. But the compensations include the possibility of living in beautiful country; and for those to whom rural pursuits appeal there could be few occupations offering greater opportunity of appreciating what the countryside has to offer.

The point of these reflections, applied to the practical business of managing and operating hydro-electric systems, is this. There have been complaints from more than one part of the world that it is difficult to recruit men for the operation and maintenance of hydro-electric stations, particularly those remote from large centres of population. We have not, so far, seen

many attempts, on the part of managements, to direct their public-relations activities towards letting all who are likely to be interested know of the excellent labour relations record of the hydro-electric power-production industry, and the basic advantages which it offers by way of employment to counteract the few drawbacks which such a life involves. It is perhaps worth considering that all hydro-electric managements might build up their prestige, and that of the people who work for them, by greater attention to this aspect of their service to the public, the provision of safe and stable employment under conditions that are usually at least as favourable as those offered in any other industry, and which concern the fundamentally noble task of harnessing nature's resources for the benefit of mankind, with unequalled and permanent efficiency.

Chief Joseph Dam Contracts

AS we go to press we learn that The English Electric Co. Ltd. has been awarded the contract for the power transformers for Chief Joseph dam and Westinghouse Electric Corporation that for four generators. The English Electric transformer tender of £629,000 was £25,236 lower than their own tender of last December which was rejected. For the generators the Westinghouse bid was £1,517,000 as against that of £1,570,000 from The English Electric. Tenders for four more transformers and four more generators are to be invited.

McNary Dam Transformer Contract

HOPES that the contracts for electrical plant for Chief Joseph dam might come to Britain had already been revived by the award to Ferranti Limited of the contract for six large power transformers for the McNary dam on the Columbia River by the United States Army Corps of Engineers. This firm's tender of $857,000 was the lowest, and the next lowest, of $898,000, came from the English Electric Co. Ltd. The lowest American bid, of $983,000 from the Moloney Electric Company of St. Louis, was 18 per cent. higher than Ferranti's figure.

Last year Ferranti Limited obtained the contract for nine single-phase generator transformers forming three 13·2/230 kV 100,000 kVA three-phase banks for the Garrison dam, North Dakota.

Breadalbane Scheme

THE construction of six dams and seven generating stations and the enlargement of Loch Lyon are the main features of a new hydro-electric scheme in the Breadalbane district of Perthshire. The scheme, estimated to cost £15,103,000, was prepared by the North of Scotland Hydro-Electric Board to develop the water power resources of Upper Glen Lyon, Loch Daimh, Loch Giorra, streams in Glen Lochay and Glen Dochart, the headwaters of the Rivers Almond and Lednock, of Lochan Breachlaich and other streams to the south of Loch Tay, tributaries to the south of the River Earn and the headwaters of Monachyle Burn. The scheme will have a total installed capacity of about 88,500 kW and will produce an average of 304 million kWh per annum. It has now been confirmed by the Secretary for Scotland.

A dam about 96 ft. high across the River Lyon near Lubreoch will enlarge Loch Lyon, and additional water will be brought in by an aqueduct from Glen Lochay. A generating station will be built into this dam to discharge water to a second dam near Murlaganmore in Glen Lochay. Lochs Daimh and Giorra will be enlarged and united by a dam about 92 ft. high and the water led to a generating station at Stronuich. A reservoir will be created by damming the Monachyle Burn to feed a generating station on the River Dochart, near Luib railway station. In the St. Fillans section of the scheme a dam about 60 ft. high will be built so that Lochan Breachlaich will become a reservoir from which water will be led by a tunnel to a generating station in Glen Ledock. A new loch will be formed by a dam across the River Lednock near Bovaine to feed another station near St. Fillans, and water from the River Almond and other streams will be diverted into this loch. Water will be led from Loch Earn by a tunnel with an intake near the outlet of the loch to a generating station near Dalchonzie.

The Tiszalök Project, Hungary

THE construction of the Tisza dam and hydro-electric and irrigation project at Tiszalök, north-east Hungary, is now entering its final stages. It is anticipated that the turbines will be in operation by May, 1954.

The 90 ft. dam is now almost completed and the foundations for the turbines and generators have been laid. A lock is being provided to accommodate vessels of 1,000 tons to the upper reaches of the Tisza, which will thus be made navigable for another 50 miles.

At the same time as the power station begins work, the first 40 miles of the Hortobágy ship canal, running due south from the dam, will be brought into use. As yet this canal is completed as far as Balmazujváros, a distance of about 28 miles. The lock at the northern entrance to this canal has already been excavated, and work on the concrete lining has begun.

International Use of Austrian Water Power

THE objective of the international exchange of power in Europe has been brought a step nearer by the formation of an international association to study the hydro-electric potentialities of Austria with a view to joint exploitation for the benefit of Europe generally. Members of the association include the Austrian Electricity Authority, Electricité de France, the West German Electricity Authority with its subsidiaries Bayernwerk, Rheinische-westfaelische E-Werke, and Energieversorgung Schwaben, and the four Italian power companies constituting the Senel group. It is hoped that Swiss and Benelux companies will join later. The association has its headuarters at Innsbruck and is studying the legal, financial and technical requirements for joint exploitation.

Madras Shortage

DESPITE the increase in installed capacity from 98,000 kW in 1946 to 183,000 kW in 1951, the shortage of electric power is proving a source of anxiety in Madras. The Grid comprises three hydro-electric stations, five thermal stations and numerous small diesel stations. About 75 per cent. of the power generated is from the hydro-electric stations. Despite

working to full capacity it has not been possible to meet current demand. A recent review of the power position of the State shows a deficit of about 40 per cent. and the demand is continually increasing. To maintain supplies for essential purposes, the Madras Government in recent years has often had to reduce supply to other consumers, the extent of which depended upon the water position in the reservoirs at Mettur, Pykara and Papanasam. The range of reduction has varied between 25 and 67 per cent.

Kiewa Progress

ALTHOUGH work on part of the Kiewa scheme was suspended some time ago for financial reasons, satisfactory progress is reported on some other parts of the development. Clover dam, which will form a pondage for No. 4 station near Mount Beauty village, is about 70 per cent. completed, and excavation for the underground power station is well advanced. The four 15·4 MW generating sets should be in operation by 1953/54. For No. 1 station, forming the upper development, upwards of 940 ft. of the headrace tunnel, or about 78 per cent. of the total, has been excavated, but work has been suspended on the upstream end, and the four 16 MW turbo-alternators will not be installed until 1955/56. Societé Etudes et Enterprises, who are carrying out this work, have also made a preliminary study of the various alternatives for No. 2 development.

Schemes in the Philippines

WHAT is claimed to be one of the largest and highest rockfill dams in the world is under construction at Abuklao on the Agno River, Luzon. It will be 430 ft. high and will serve three 25 MW sets in an underground station.

Work is also proceeding on the Maria Cristina project on the Agus River. The present scheme consists of a 38 ft. diversion dam, an approach channel round the falls, and a penstock to the power station at the foot of the hills. Initially a single 25 MW set will be installed, but further similar units can be added to a total of 200 MW.

Power in Italy

THE output of electric power in Italy during 1952 showed a marked increase with 30,137 million kWh sent out as compared to 28,498 million in 1951 and 23,919 million in 1950. Progress was due to increases in both hydro-electric and thermal output. For the hydro stations the figures for the three years were 20,972 million kWh in 1950, 25,750 million in 1951, and 26,532 million in 1952.

Important hydro-electric stations under construction or inaugurated during last year include the Tavazzano plant of the Societa Termoelettrica Italiana, and the Molveno Lake project in the Trento province. The latter comprises several power stations, the most important of which will be the Santa Massenza No. 1 power station, recently put into commission. The turbine room at this station is built in a large underground cavern measuring 192 by 28 by 28 m. This plant, which operates with Pelton turbines, has a maximum head of 590 m., an average head of 533 m. and a minimum head of 460 m.

The demand for industrial power is likely to increase in Italy during the next few years with the Italian State Railways completing the electrification of the Messina-Catania-Syracuse and of the Messina-Palermo railways in Sicily.

Plant for Turkey

THE Turkish Government has placed an order for the entire electric and mechanical equipment for two hydro-electric stations with the Elin A.G., Vienna. The plants, having a total capacity of 18,000 kW, are to be erected in Anatolia. In addition to its standard products, such as power generators, transformers and switchgear, the Austrian firm will also be responsible for the supply of water turbines and other mechanical equipment.

Atomic Energy—the Competitor of the Future?

IN his presidential address to the British Electrical Power Convention at Torquay last month, Sir John Hacking said that the estimated internal demand for coal in Britain for 1961 would be 230 million tons, and that in his view it might be 300 million tons in 50 years time. A substantial gap between production and demand therefore remained to be bridged.

Full development of the known potential hydro-electric resources of Great Britain would produce additional energy equivalent to an annual consumption of 3 million tons of coal. Development of wind power, taking a very optimistic view, would save another million tons of coal. Tidal power also offered possibilities, and the Severn Barrage, if constructed, would save about a million tons of coal a year.

There remained the nuclear sources of energy. Sir John Cockcroft had indicated that the capital cost of a power station using natural uranium was unlikely to exceed twice that of a conventional steam power station. The fuel cost would depend not only on the initial cost of the uranium but also on the working life of each charge. It seemed probable that the fuel cost would be less than that of a coal-fired station, particularly when credit was allowed for the value of the plutonium recovered. At present both capital cost and fuel cost were, to a great extent, speculative, and reliable comparisons would only be possible after practical working experience.

World reserves of uranium, assuming 100 per cent. utilisation, were many times greater than the known reserves of coal and oil. It was possible to convert thorium into the isotope U.233 which could be used as a nuclear fuel, and the quantity of thorium was nearly three times as great as that of uranium. There seemed little doubt that in terms of the next 100 to 200 years nuclear fission would provide an abundant source of energy, which would be delivered in the form of electricity.

Hydro-electric engineers will note these cost comparisons with interest, but it seems unlikely that atomic energy will challenge water power, where available, on the score of cost per unit generated.

Tothill Press Limited. Mr. B. W. C. Cooke, Mr. J. S. Hunter and Mr. S. Newman have been appointed Executive Directors of Tothill Press Limited, the company owning and publishing this journal.

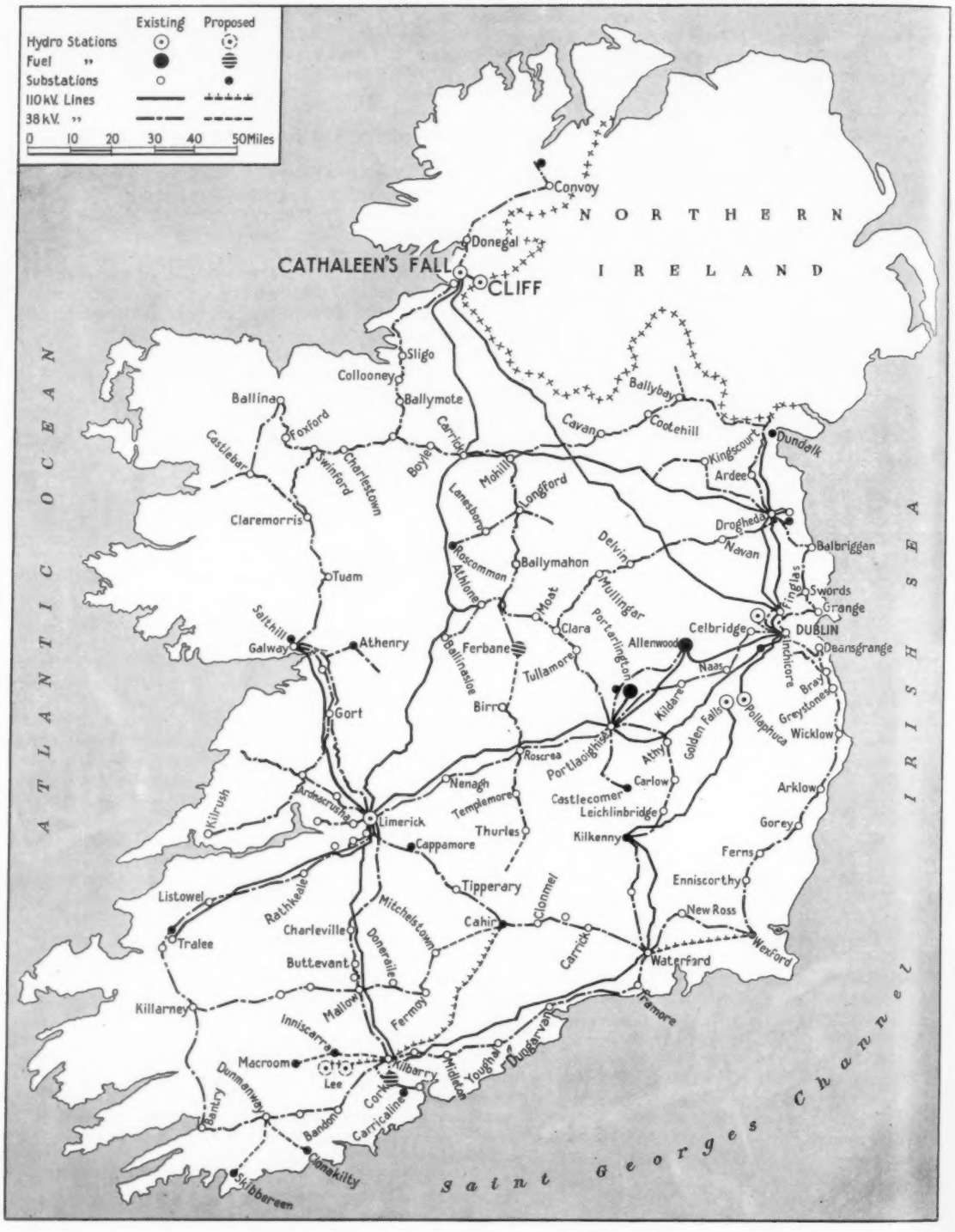

Fig. 1. Map of Eire showing the disposition of Cathaleen's Falls and Cliff stations in relation to the Irish electricity network

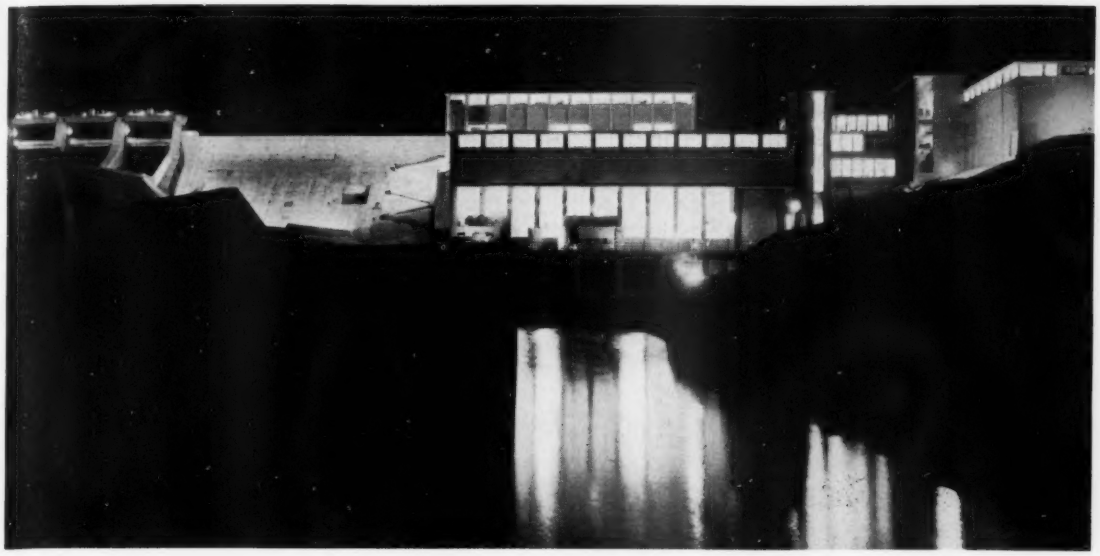

Fig. 2. Cathaleen's Falls station at night

The Erne River Development

The latest addition to the hydro-electric resources of Eire is the development on the River Erne in County Donegal. Two stations, at Cliff and at Cathaleen's Falls respectively, utilise a fall from about 152 ft. O.D. to sea level and have a present combined capacity of 55 MW. The scheme is laid out for an ultimate development of 87·5 MW.

WHEN the Shannon scheme was commenced in 1925, gloomy prophets were not wanting who predicted that the load for this 80 MW station would never become available. But since the Irish Electricity Supply Board, which was established in 1927, began to supply consumers in 1929, demand has increased to such good purpose that the Ardnacrusha station on the Shannon was followed by the Pollaphuca, Golden Falls, and Leixlip stations on the Liffey, and these have now been supplemented by the Cliff and Cathaleen's Falls stations on the Erne. These hydro-electric stations are in addition to thermal plants, fired by coal, oil and peat. Table I gives a list of the generating stations now in commission in Eire, and shows that practically half the installed capacity is now hydro-electric.

Since 1929, in fact, if the war years 1941 to 1945 are excluded, the demand for electricity has doubled every 5½ years, and as the latest available figures* show, the annual demand has reached upwards of 1,029 million kWh. Domestic requirements form the heaviest demand, amounting to 42 per cent. of the total, followed by industrial power 34 per cent., large-scale cooking, water heating and space heating 13 per cent., general and commercial lighting 7 per cent., and miscellaneous uses 4 per cent. This steady increase in load afforded ample justification for the River Erne development, and work is now proceeding on the erection of a further 220 MW of generating plant, of which 37 MW will be hydro-electric, including 10 MW on the Erne and 27 MW on the River Lee.

TABLE I — GENERATING PLANT CAPACITY OF ELECTRICITY SUPPLY BOARD, IRELAND

	Station	Installed MW	kWh × 10⁶ For year ended March 31, 1952	kWh × 10⁶ Estimated for an average year
Hydro-electric	Ardnacrusha (Shannon)	80	303	310
	Pollaphuca (Liffey)	30	24	22
	Golden Falls (Liffey)	4	9	9
	Leixlip (Liffey)	4	15	10
	Cliff (Erne)	10	49	62
	Cathaleen's Falls (Erne)	45	57	153
	Total hydro-electric	173	457	566
Peat	Portarlington	25	130	90
	Allenwood	40	15	135
	Total peat	65	145	225
Coal and oil	Pigeon House	95	368	350
	North Wall	12	57	60
	Cork (old)	5	3	negligible
	Total coal and oil	112	428	410
	Grand total	350	1030	1201

As is to be expected in a largely agricultural country

* Twenty-fifth Annual Report of the Electricity Supply Board, Ireland, for the year ended March 31, 1952.

the transmission and distribution system is extensive relative to the generating capacity. Main transmission is at 110 kV with secondary transmission at 38 kV. Distribution is at 10 kV except in the Dublin city area where the existing 5 kV system has been retained. A map of the electricity supply system of Eire, showing the existing and projected generating stations, transformer stations, and main and secondary transmission lines, appears in Fig. 1, and Table II gives leading figures of the transmission and distribution system.

TABLE II — ELECTRICITY SUPPLY BOARD'S TRANSMISSION AND DISTRIBUTION SYSTEM

Voltage	Number of Stations	Circuit Length of Lines and Cables km
110 kV	7	1518
38 kV	110	2861
10 and 5 kV other than rural	2760	5268
Rural lines (10 kV and L.T.)	7009	10950

Some features of the transmission and distribution system are:—

(a) Practically all stations and lines are designed by the Board's staff and erected by direct labour.
(b) The majority of the 110 kV lines have horizontal conductor spacing and double wood-pole supports; earth wires are used for only 2 km. out from stations.
(c) Arc-suppression plant is installed throughout the 110 and 38 kV systems.
(d) Air-blast and low-oil-content circuit breakers are extensively used.
(e) On-load tap-changing transformers with a long range of tappings are used for voltage regulation.
(f) There is extensive rural electrification.

The Erne Development

The Erne is the second largest river in Ireland, the Shannon, of course, being the largest. It rises in County Cavan in the Irish Free State, flows through two major lakes, Upper and Lower Loughs Erne in County Fermanagh in Northern Ireland, and returns to the Free State at Belleek, whence it descends through County Donegal a distance of about five miles to the sea at Ballyshannon. It is nearly 60 miles long, has a catchment area of 1,530 sq. miles, an average annual flow, based on 40 years' records, of 3,600 cusecs, and a maximum flood of 11,000 cusecs. The average annual rainfall is 41·4 in.

Prior to the development works the normal water levels in the Upper and Lower Loughs were 153 ft. and 152·66 ft. O.D., and were regulated by sluices at Belleek about four miles below the outlet from the Lower Lough. In times of flood, however, the river channel between the Upper and Lower Loughs and that forming the outlet from the Lower Lough were not large enough to discharge the inflow, and the levels rose to 158·0 ft. and 154·6 ft. O.D. respectively, flooding some 24,000 acres of land, chiefly round the shores of the Upper Lough. Seeing that the effect of the hydro-electric scheme will be to relieve this flooding the co-operation of the Government of Northern Ireland in carrying out the necessary works in their territory has been willingly available. These works include the deepening of the 11½ mile channel between the Upper and Lower Loughs and the building of sluice gates in this channel to prevent

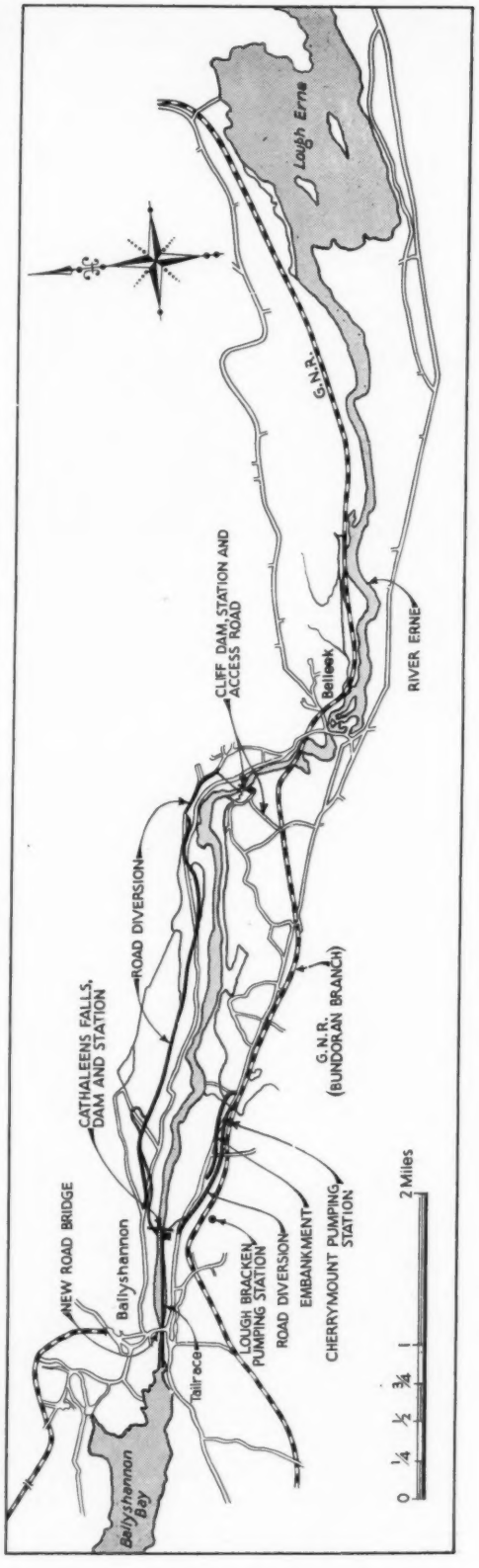

Fig. 3. Map of the Erne River development showing the civil-engineering works involved

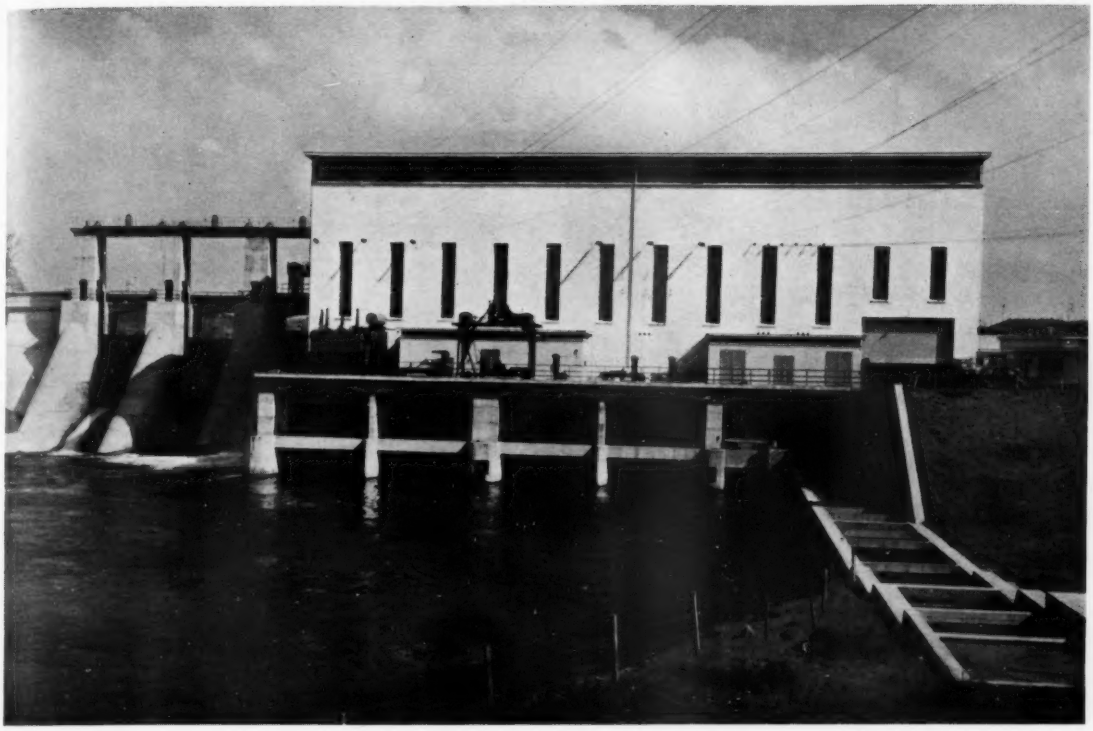

Fig. 4. Downstream view of Cliff station

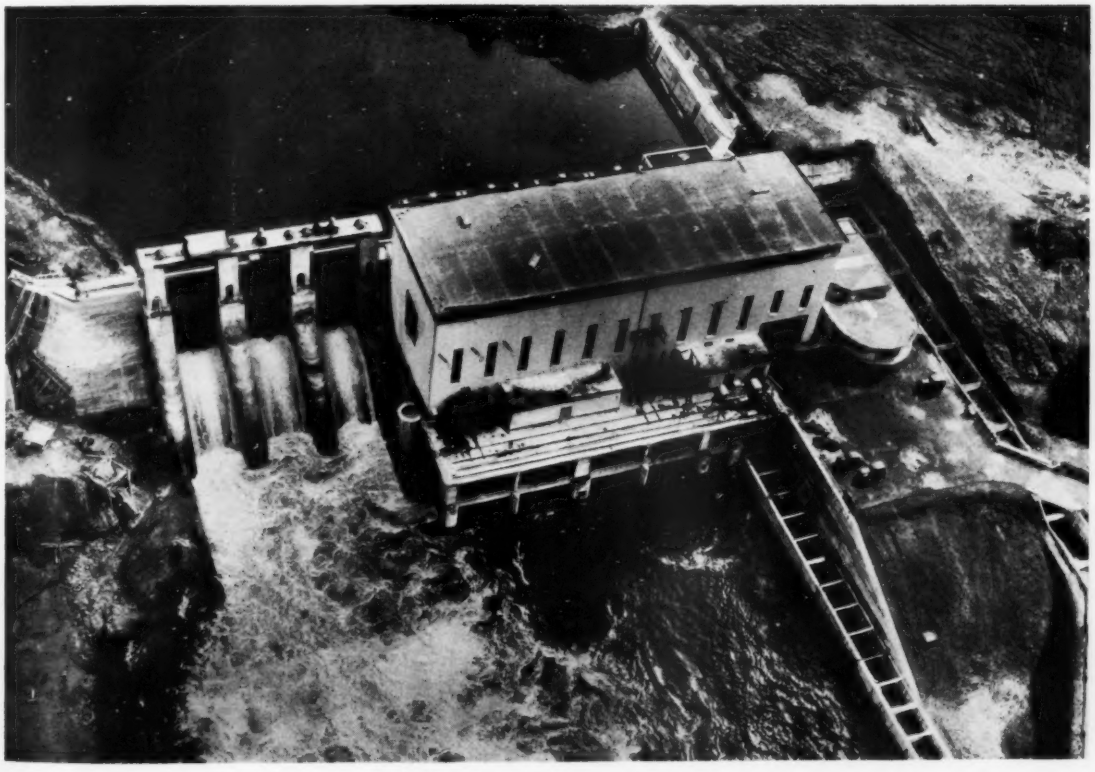

Fig. 5. Aerial view of Cliff station

Fig. 6. Aerial view of Cathaleen's Falls station during the latter stages of construction

the level of the Upper Lough from falling below 150 ft. O.D. The channel from the Lower Lough to Belleek—a distance of about four miles—is to be enlarged, the sluice gates at Belleek are to be dispensed with, and the flow regulated at Cliff, where it will be possible to control the Upper Lough to a maximum level of 153 ft. O.D. and the Lower Lough to 152 ft. O.D. A drawdown to 150 ft. O.D. in the Upper Lough and to 147 ft. O.D. in the Lower Lough is allowed for, giving a storage of 6,830 million cu. ft. or about 10 per cent.

From the hydro-electric standpoint it is fortunate that the main fall from 152 ft. O.D. to sea level is concentrated in the short distance between Belleek and Ballyshannon. From the old sluice gates already mentioned the river enters a gradually deepening gorge about half a mile long, at the end of which the river bed is at a level of about 100 ft. O.D. The valley then widens out with its right ridge roughly parallel to the river, while its left side sweeps out in a wide curve, coming back to the river again about three-quarters of a mile above Ballyshannon. Thence a series of rapids, now submerged, carried the river into the sea at a bed level of about 20 ft. O.D. Spring tides in Ballyshannon Bay vary between +17 ft. and +3·5 ft. O.D.

In the preliminary investigations two alternative methods of development were considered, one being to build a single station for the total head, and the other to utilise the head in two stages by building two stations with an intermediate reservoir. The single station offered the obvious advantages of smaller staffing and simpler operation, but its capital cost proved to be so much in advance of the two-station scheme that it could not be justified. Accordingly the development was finalised on the basis of an upper station at Cliff near the outlet of the upper gorge, and a lower station at Cathaleen's Falls about three-quarters of a mile above Ballyshannon. The distance between the two stations is about three miles and is occupied by a new storage basin.

A map of the Erne River development is given in Fig. 3, and the works involved comprise the following: the erection of sluices between the Upper and Lower Loughs (carried out by the Government of Northern Ireland); the deepening of a four-mile length of river out of Lower Lough Erne; the removal of the old sluice gates at Belleek; the construction of a dam and power station at Cliff and of a dam and power station at Cathaleen's Falls; the construction of an earth embankment on the left side of the valley between Cliff and Cathaleen's Falls stations; the erection of two small drainage pumping stations; the excavation of a tailrace between Cathaleen's Falls and the sea; the construction of about four miles of diversion roads; and the reconstruction of a railway bridge near Belleek and of two road bridges at Cliff and at Ballyshannon respectively.

To deepen the channel out of Lower Lough Erne requires the removal of about 760,000 cu. yards of mixed rock and earth, and when completed will be able to cope with floods of 11,000 cusecs with a level of 152 ft. O.D. on Lower Lough Erne when the water upstream of Cliff is at its minimum level of 143 ft. O.D. Furthermore, it will enable Cliff station to run at 100 per cent. capacity at lough levels down to 150·4 ft. O.D. and at 50 per cent. capacity at a level of 147 ft. O.D.

At Cliff the dam is of the mass concrete gravity type, 60 ft. high and 690 ft. long, and at the maximum water level of 152 ft. O.D. creates a small basin of 820,000 sq. ft. surface area, but pending the completion of the upstream works the level is being held at about 143 ft. O.D.

The river at this point is about 200 ft. wide, and about two-thirds of this width on the left-hand side is occupied by the power station, which at present contains one 10 MW Kaplan set. Space is available for a second set, which is expected to be in commission in 1954. To the right of the station is the spillway, which is equipped with three 20 ft. sluice gates.

Fishing is an important consideration on this river, and both the Cliff and Cathaleen's Falls stations are provided with salmon and elver passes.

The earth embankment on the left side of the valley between Cliff and Cathaleen's Falls protects the Belleek—Ballyshannon branch of the Great Northern Railway. It is about threequarters of a mile long, with a maximum height of 30 ft., and bounds the intermediate storage basin between the two stations. This basin is designed for a high-water level of 112 ft. O.D., a working low-water level of 105 ft. O.D., and an emergency low-water level of 100 ft., giving a normal storage of 155 million cu. ft. and an additional emergency reserve of 88 million cu. ft.

At Cathaleen's Falls the dam is also of the mass concrete gravity type, and is 1,000 ft. long by 90 ft. high. On the right bank is the spillway, which is of an unusual design and was the subject of detailed model tests. The water is controlled by three 36 ft. sluice gates, and descends to tailrace level in three stages. A scour outlet through the dam is also provided.

Towards the left of the dam is incorporated the power-station intake structure. The station itself is located slightly below the toe of the dam and is fed from the intake structure through penstocks. To provide a tailrace of adequate capacity a channel 48 ft. wide, 26 ft. deep and 4,500 ft. long had to be cut between the power station and Ballyshannon Bay. Extensive model tests were carried out in this case also, to determine the most suitable device to control the discharge of the tailrace waters into the bay.

At present the main generating equipment at Cathaleen's Falls consists of two 22·5 MW Kaplan sets. The works have been left so that the station can be extended to house a third set if desired, but such an extension is not on the present programme.

Although Cliff station is controlled locally, the output from both stations is supervised from the control room at Cathaleen's Falls, and is handled by an outdoor switching station on the south bank about 1,000 yards upstream of Cathaleen's Falls.

Civil Engineering

The Erne River development was designed in its entirety by the technical staff of the Electricity Supply Board under their Chief Engineer, Mr. P. J. Murphy, M.E., M.I.E.E. The civil engineering was carried out under the direction of the Chief Civil Engineer to the Board, Mr. J. MacDonald, B.Sc., B.E., A.M.I.C.E., and the main civil-engineering contractors were the Cementation Co. Ltd., Doncaster, who have now built four of Eire's six hydro-electric stations. The difficulties of access and of long rail and road hauls that are so characteristic of hydro-electric construction were encountered in due measure, but local material was used in very high proportion, and a special railway siding was built near the Cathaleen's Falls site to handle material and equipment arriving from elsewhere. A high percentage of the labour, also, was native, and much of it had to be trained from scratch. The total quantities involved in the whole scheme were approximately:—

Fig. 7. Hoist and conveyor transferring spoil from the power-station excavation to the crushing and screening plant seen in the background

Earth excavation
and filling ... 400,000 cu. yards
Rock excavation 500,000 cu. yards
Concrete ... 200,000 cu. yards

The various civil-engineering problems encountered and the constructional methods employed will be discussed when each part of the scheme is described in detail,* but it will be convenient at this point to refer to the crushing and concrete-mixing plant and other services general to the scheme.

Material for aggregate was drawn almost entirely from the limestone excavations for Cathaleen's Falls station and the tailrace, and a central crushing and mixing plant was set up on the north bank conveniently near to the dam site. The power-station excavation was taken out in three 20 ft. benches, and to facilitate the transfer of the spoil to the crushing plant a shaft 80 ft. deep was sunk in the south bank near the excavation and a 45° sloping shaft was cut from the floor of the excavation to the bottom of the vertical shaft. A 1 cu. yard scraper bucket gathered the spoil into the sloping shaft whence it was fed into a 4 cu. yard skip hoist in the vertical shaft. At the surface the spoil was transferred to a belt conveyor extending across the river to the crushing plant, as seen in Fig. 7.

Fig. 8. Part of the earth embankment, taken before flooding, forming the side of the reservoir between Cliff and Cathaleen's Falls stations

The crushing plant was equipped with two 30×18 in. jaw crushers leading to a scalping screen separating out 3 in. and $1\frac{1}{2}$ in. material. Secondary breaking was accomplished by two hammer mills, final sizing being carried out by two three-decked screens giving aggregate of 3—$1\frac{1}{2}$ in., $1\frac{1}{2}$—$\frac{3}{4}$ in., $\frac{3}{4}$—$\frac{3}{16}$ in., and minus $\frac{3}{16}$ in. (sand), the material being washed during screening by air and water jets. The sand was then passed through a bucket dewaterer, and all four sizes were stocked in two sets of 500 ton steel storage bins. Natural sand was brought from a distance of 26 miles and was stored in two further 500 ton bins, but was used only for upstream and spillway faces and a few other important points.

Ordinary Portland cement was used, and was brought by rail in bulk in 10 ton cars and pneumatically conveyed a distance of 2,000 ft. from the siding to the storage silos, of which there were two, each of 300 tons capacity, placed in line with the corresponding row of aggregate storage bins.

A belt conveyor extended in a tunnel under each row of storage bins, feeding the batch hoist of its own mixer. Batching was by volume in the case of the aggregate, and by weight in the case of the sand and cement. Each of the two mixers was of 1 cu. yard capacity.

Compressed air for drilling and other services was supplied from a central compressor house containing 13 Ingersoll Rand machines having an aggregate capacity of 5,000 cu. ft. per min. Mains up to 6 in. in diameter delivered the air to all points of application, including the works at Cliff.

Electric power from the Electricity Supply Board network was brought to all major construction sites. Offices, staff bungalows and a camp to house 500 men were erected on the north side of the Cathaleen's Falls site.

Bridges

Of the diversionary and reparation works, brief mention may be made of the bridge reconstruction at Ballyshannon. This work was important not only because the bridge connects the two halves of the town but because it forms the only road connection wholly in Eire between Donegal and the rest of the Free State.* The old bridge had eleven arches, the largest having a span of 21 ft., and formed a definite obstruction to the cutting of the tailrace between Cathaleen's Falls and Ballyshannon Bay. To carry the bridge over the tailrace it was necessary to replace five arches on the northern end of the bridge by a single span of 76 ft., which was constructed in reinforced concrete with masonry-faced spandril walls and parapets. A temporary bridge was thrown across the river, and a concrete cofferdam, equipped with wooden gates at the upstream end, was built down the approximate centre of the river to enable work on the bridge and this section of the tailrace to proceed in the dry. Advantage was taken of the reconstruction to widen this section of the bridge to provide a 24 ft. carriageway with two 8 ft. footpaths. The southern half of the river bed has been left dry by the cutting of the tailrace, and this will facilitate widening the rest of the bridge when desired. The contractors for the bridge and for the excavation of the tailrace in its immediate vicinity were McLaughlin & Harvey Limited.

The railway bridge that has been reconstructed carries the Belleek-Ballyshannon line over the Erne near Belleek, and was formerly of the lattice-girder type with the track set high between the girders. At the new river level the clearance would have been dangerously low, but by replacing the lattice-girder construction by a portal-type bridge it has been possible to maintain a clearance of 4—5 ft. above maximum water level without altering the level of the permanent way. New piers were built up on the inside of the old ones, reducing the span from 153 ft.

* An earlier account of the civil-engineering work on this scheme was published in WATER POWER, November-December 1949, page 235, "The Erne Development Scheme," by C. F. Grundy, M.Eng., M.I.C.E., Chief Civil Engineer, The Cementation Co. Ltd.

* For a full account see a paper "Reconstruction of Ballyshannon Road Bridge" read by P. A. Jackson, B.A., B.A.I., A.M.I.C.E., on January 5, 1948, to the Institution of Civil Engineers of Ireland.

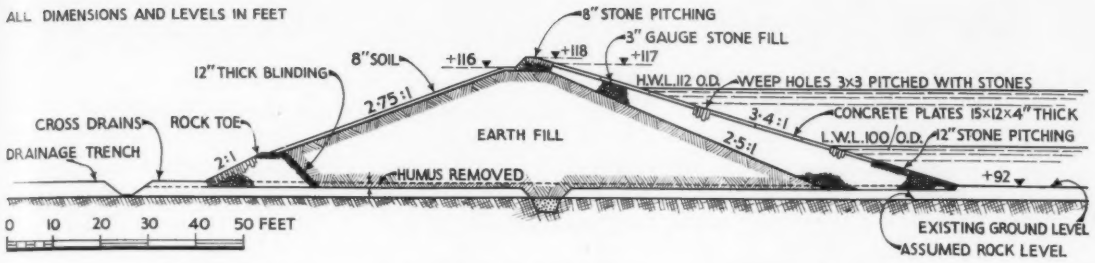

Fig. 9. Typical cross section of Cathaleen's Falls reservoir embankment

to 140 ft. 4 in., and the line was closed and replaced by a bus service for about four weeks while the changeover took place. The contractors were Dorman Long & Co. Ltd.

Earth Embankment above Cathaleen's Falls

A view of the earth embankment bounding the reservoir between Cliff and Cathaleen's falls appears in Fig. 8, and a typical cross section is given in Fig. 9. Earth was obtained partly from a borrow pit at the upstream end of the bank and partly from a roadway cutting at the downstream end. Within a distance of 400 yards from the borrow pit the earth was drawn by a 6 cu. yard scraper, but elsewhere it was excavated by power shovel and transported in $1\frac{1}{2}$ cu. yard 2 ft. gauge wagons. Sheepsfoot rollers were used initially but plain rollers were later found to be more satisfactory.

The core trench is mostly in rock but in some parts is in boulder clay. The portion in rock is filled with concrete to assist pressure grouting, that in boulder clay being filled with earth and the junction between the earth and concrete fill made with galvanised corrugated sheet. The top of the concrete is grooved along its length and filled with selected fine clay. Grouting was accomplished by primary, secondary and tertiary series of grout holes drilled to depths up to 60 ft., primary holes being 25 ft. apart and at an angle of 30° to the vertical. Suspected zones of seepage were treated specially, and at one point holes 2 ft. apart over a distance of 50 ft. were required to seal off the discharge from a lough.

Seeing that the new reservoir interferes to some extent with the natural drainage of the valley, two small automatic pumping stations, at Cherrymount and Lough Bracken respectively, have been built to lift drainage water into the reservoir. Each station houses two Vickers-Gill 35 cusec pumps.

NOTE: Further articles will describe Cliff and Cathaleen's Falls stations in detail.

Brazilian Traction's Report

According to the 1952 annual report of Brazilian Traction, Light and Power Co. Ltd., the demand for electric energy on both the Rio and São Paulo systems again increased during the year, but because of a continuing insufficient water supply and a lack of generating capacity, it was impossible to satisfy fully all consumers' requirements. As circumstances and public authorities permitted, electric energy was transferred between the two systems. Experiments to induce precipitation were continued with the co-operation of the Brazilian Government and met with some success in the Rio area.

Total sales of electric energy in 1952 were 4 per cent. above 1951. Total generation, however, was 6·9 per cent. above 1951; the difference between the increase in generation and the increase in sales was largely accounted for by the additional amount of energy required by the company's pumping stations following the inauguration in March 1952 of the Paraíba-Piraí diversion project. During the year the number of consumers increased by 7·9 per cent. to a total of 1,056,871 at the end of 1952.

Water storage for the Rio system remained at a critically low point during January and February of 1952, but this shortage was alleviated some weeks later by heavier rainfalls and by the inauguration of the first pumping units of the Paraíba-Piraí diversion project. The second set of pumps was placed in operation at Vigário and Santa Cecilia on August 5 and September 11 respectively.

The output of the run-of-river plant at Ilha dos Pombos was reduced owing to below-average flows of the Paraíba River from April to October, 1952. This placed a greater burden on the Fontes plant, making it necessary to draw down a greater amount of water from the Lajes reservoir than had been anticipated.

There was no increase in installed generating capacity on the Rio system during the year, but in spite of adverse factors the Rio system generated 2,024,691,100 kWh in 1952, compared with 1,701,991,100 kWh in 1951, an increase of 19 per cent. This was in large measure possible because of the additional water made available at Fontes by the Paraíba - Piraí diversion project.

Construction work on the Forçacava underground generating plant progressed favourably during the year. At the end of 1952 excavation for this plant was almost complete and concrete structural work, including foundations for the turbines and generating equipment, was under way. Work had also been started on placing sections of the steel lining in the pressure shaft. The first two generating units of the Forçacava plant are scheduled to go into service during the latter part of 1953.

On the São Paulo system the output of the Itupararanga plant and the small run-of-river plants was reduced as a result of low water levels in the Sorocaba reservoir and below-average flows of the Tietê River. In general, rainfall in the run-off areas of the reservoirs of the São Paulo system was considerably less than the 30-year average. Total generation on the São Paulo system in 1952 was 3,599,671,676 kWh, an increase of 42,113,172 kWh or 1·2 per cent. over generation in 1951.

Some Modern Methods of Site Survey

A description is given of some interesting survey work which was done for the Errochty hydro-electric project, and is mainly devoted to the accurate triangulation of Errochty dam. This final part of the article deals with aspects of other survey methods which may not be generally known.

By E. T. HAWS, M.A., A.M.I.C.E.

PART TWO

Third-Order Triangulation

For minor triangulations, speed is the main factor but good results can be achieved with a quick-reading instrument such as the T.63.

The main differences in technique to that advised for the Tavistock are:—

(1) The theodolite may be transited on the last station instead of closing on the R.O.

(2) Two complete rounds on two faces should be sufficient. The author allows 10″ maximum difference between reduced observations on any angle, and a 20″ closure on triangles, interpolating each reading of the horizontal scale to 5″. Triangles rather than quadrilaterals are used. The co-ordinates computed from the T.63 triangulation of the permanent triangulation stations varied by a maximum of 0·05 ft. from those computed from the final Tavistock triangulation.

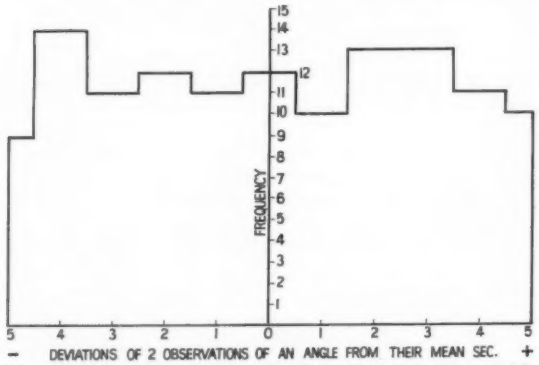

Fig. 10. Frequency curve for T.63 triangulation of 22 triangles

Fig. 10 shows the frequencies of the deviations of individual readings of an angle from the arithmetic mean of the readings of that angle, for a recent T.63 triangulation involving 22 triangles. It will be seen that the frequency distribution is nearly rectangular, as the range $\pm 5''$ is within the direct readings of the theodolite.

Resection

A simple method of establishing the position of a theodolite set up in the Errochty dam area now exists in resection on to three of the collinear setting-out pillars on the reference line C_S — C_N. Setting up at *D*, Fig. 11, the angles α and β are measured. Distances *l* and *m* between any three pillar stations are known.

$$\text{Then } \tan \gamma = \frac{m \sin \alpha \sin \eta}{l \sin \beta + m \sin \alpha \cos \eta}$$

where $\eta = 180 - \alpha - \beta$.

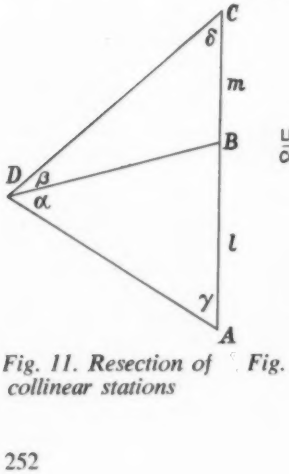

Fig. 11. Resection of collinear stations

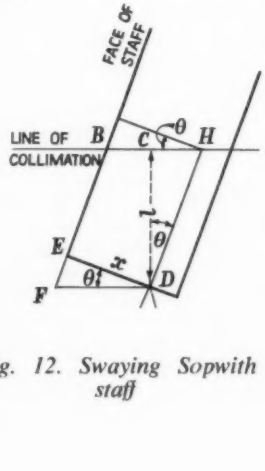

Fig. 12. Swaying Sopwith staff

Precise Levelling

It was found extremely difficult to carry a precise level across the dam site and back using natural change points. Any rock outcrops were being established as permanent bench marks at about 20 to 30 ft. vertical intervals.

Eventually hobnailed pegs were used at 5 to 6 ft. vertical intervals as change points. Two observers used two Cooke, Troughton and Sims precise levels, two chainmen, and the bottom 6 ft. section of a 16 ft. Sopwith staff with a hold-on staff spirit level. Observers and chainmen worked in pairs, but using the same staff and change points. Foresights and backsights were kept approximately equal. The instruments were never moved until the two observers had agreed the difference betwen adjacent change points to 0·002 ft. or less, allowing for variation in staff correction. The total closing errors of the two observers after covering one mile longitudinally and a total of 560 ft. vertically were 0·040 ft. and 0·027 ft. respectively, the total number of change points being 127.

Swaying the staff is often quoted as a means of obtaining accurate levels, but the reading is always more difficult to make, and the minimum is actually in error unless the chainman keeps the very front of the staff on the change point. This is shown in Fig. 12, where

CD = l = true reading of staff.
x = ED = distance of change point from face of staff.
It can be shown that if total backswing $> \theta = \sin^{-1} x/l$
then minimum reading on staff $= \sqrt{l^2 - x^2}$
But if total backswing $< \theta = \sin^{-1} x/l$ then the minimum reading will occur at the limit of the backswing and $y_{min} = l \sec \theta_{max} - x \tan \theta_{max}$
If $l = 0{\cdot}5'$, $x = 0{\cdot}04'$, and $\theta_{max} = 5°$
$x/l = 0{\cdot}08$ and $\sin \theta = 0{\cdot}087$
$\therefore \sin^{-1} x/l < 5°$ and minimum reading $= \sqrt{l^2 - x^2}$
$= 0{\cdot}498$, an error of 0·002 ft.

So near the bottom of the staff, the chainman would probably be told to hold the staff still. There must, however, be some limiting height at which he is told to start swaying it.

If $l = 1{\cdot}6$ ft., $x = 0{\cdot}16$, $x/l = 0{\cdot}1 > \sin 5°$
Then minimum reading is at 5° backswing
$= 1{\cdot}6 \sec 5° - 0{\cdot}16 \tan 5°$
$= 1{\cdot}6\ (1{\cdot}0038 - 0{\cdot}0087)$
$= 1{\cdot}592$ ft.
Error = 0·008 ft.

Tacheometry

The Williamson tacheometric system was used for all topographical surveys and rough traverses. Field work is reduced to reading upper and lower stadia hairs and the horizontal and vertical circles. The theory can be seen from Fig. 13 and equations (1), (2) and (3).

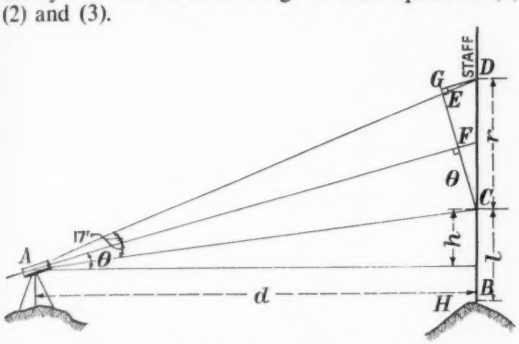

Fig. 13. Tacheometry. Angle of elevation

θ = reading of theodolite vertical circle
r = difference between readings of stadia hairs
l = reading of lower hair.
Difference in level $A - H = h - l =$
$100\,r \sin(\theta - 17'\,11'') [\cos \theta - 0{\cdot}005 \sin \theta] - l$ (1)
d, the horizontal distance =
$100\,r \cos(\theta - 17'\,11'') [\cos \theta - 0{\cdot}005 \sin \theta]$ (2)

For an angle of depression, $-\theta$, equation (1) can be transformed to
$h - l = -100\,r \sin(\gamma - 17'\,11'') [\cos \gamma - 0{\cdot}005 \sin \gamma] - r - l$ (3)
where $\gamma = -\theta$

(Note: 17′ 11″ represents the angle subtended at the centre of a circle of 100 ft. radius by a 6 in. chord and 0·005 is tan 17′ 11″.)

The functions h and d are tabulated for $r = 1$ ft. and are pro rata for other values of r. By comparison of (1) and (3) it can be seen that only one of these need be tabulated for h, as r and l are known. The functions are shown graphically on Figs. 14 and 15.

A neat method of booking is shown in Table IV with field entries headed F and reduction entries R. Columns are conveniently placed for plotting points

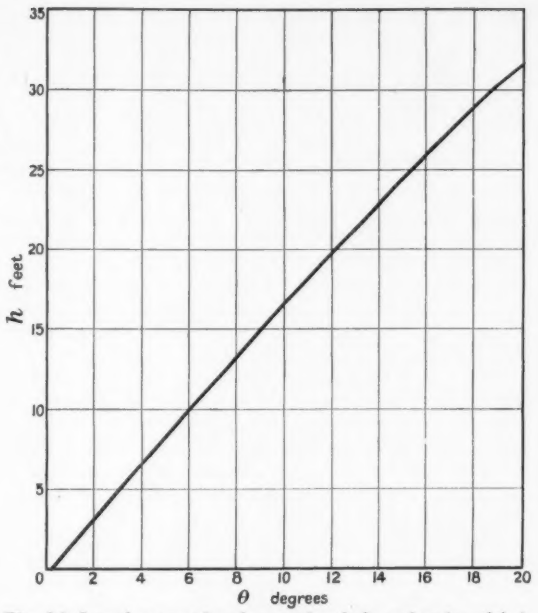

Fig. 14. Level correction for angle of elevation (r = 1 ft.)

by polar co-ordinates, using a protractor with a scale attached.

Tacheometric Booking

An accuracy of the same order as quick levelling can be obtained for small vertical angles and medium distances provided the theodolite is adjusted in collimation. The graph of h against θ, Fig. 14, shows that the difference for 1′ is actually decreasing as θ increases, and therefore the same accuracy of levelling should be attained for high values of θ. Part loss of accuracy due to the slide rule could be overcome by other means of computing. A greater loss of accuracy comes from the danger of the staff being slightly off plumb.

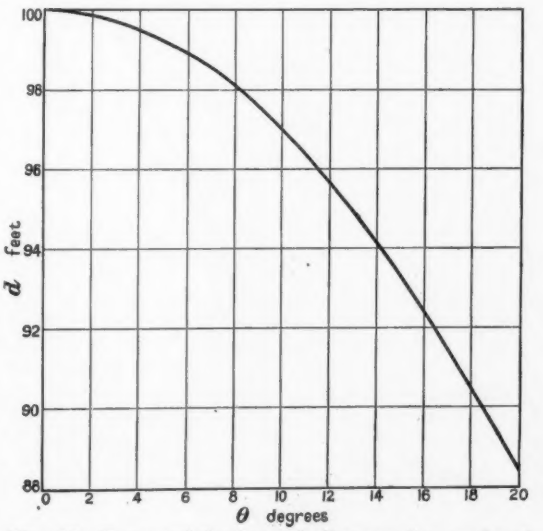

Fig. 15. Corrected horizontal distance for angle of elevation or depression (r = 1 ft.)

TABLE IV

Collimation = 968·70

	F	F	R	F	R	R
	l = lower stadia reading / $r + l$ = upper stadia reading	Vertical Circle θ	h / $h-l$	Horizontal Circle	Reduced Horizontal Distance	Reduced level = Coll. $+h-l$
1*	9 / 923	° ′ 96 23	−2·65 / −11·65	° ′ 153 55	23	957·05
2*	3 / 437	91 45	−4·87 / −7·87	169 47	137	960·83
3	5 / 685	89 50	−0·39 / −5·39	169 21	185	963·31
4	4 / 555	83 46	+15·95 / +11·95	193 16	153	980·65
5	7 / 765	78 33	+12·35 / +5·35	308 46	62	974·05

*Values of h for θ negative are from equation (1) so l is subtracted, not $(r+l)$

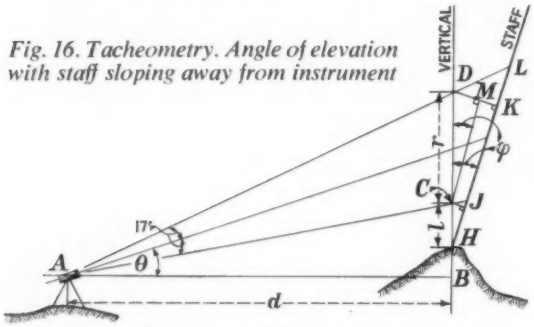

Fig. 16. Tacheometry. Angle of elevation with staff sloping away from instrument

Fig. 16 shows this condition, and equations (4) and (1) give the error in level.

θ = reading of theodolite vertical circle.

r = correct difference in reading between stadia hairs with staff vertical, for this θ.

ϕ = angle between staff and vertical.

Then value of difference in level $A - H$ computed from false readings

$$= 100 \sin(\theta - 17' 11'') [\cos\theta - 0{\cdot}005 \sin\theta] [r\cos\phi + (r+l)\sin\phi \tan(\theta+\phi+17' 11'') - l\sin\phi \tan(\theta+\phi-17' 11'')] - l\cos\phi - l\sin\phi \tan(\theta+\phi-17' 11'') \quad . \quad . \quad (4)$$

Errors for varying theodolite and staff angles

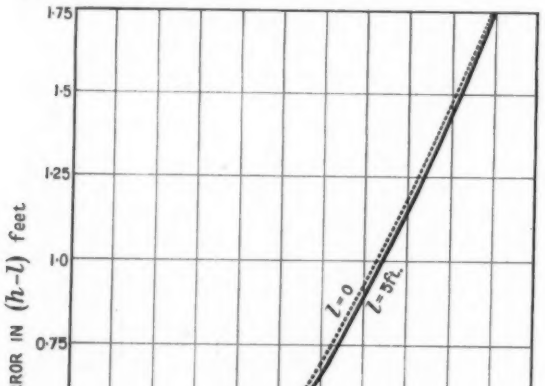

Fig. 17. Error in level correction with staff inclined at 5° away from theodolite. Theodolite elevation equals θ (correct $r = 1$ ft.)

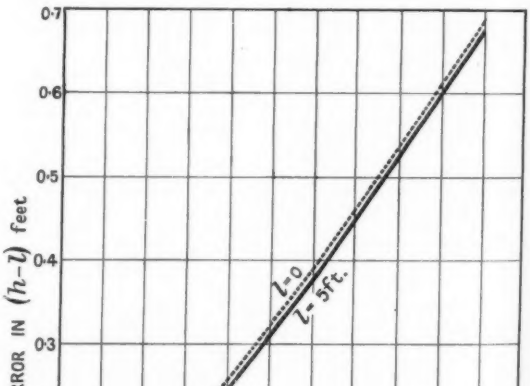

Fig. 18. Error in level correction with staff inclined at ϕ away from theodolite. Theodolite elevation = 15° (correct $r = 1$ ft.)

respectively are shown in Figs. 17 and 18. With suitable computing and staff plumbing, accuracy can be maintained up to say 30°. Such methods are only justified on bench marks and stations. With spot levels speed is foremost. Three sets of readings at different points on the staff can be taken for important sights, and taking the height of the instrument at stations is an added check.

From 300 to 400 ft. is a comfortable range for tacheometry under medium conditions. Under ideal conditions and where great accuracy was not required, the author has observed a staff 900 ft. away. Traverses can be run quickly and quite accurately using 300 to 400 ft. legs. A recent one closed to 0·2 ft. in level and 2 ft. in position after one mile horizontally and a 300 ft. rise.

On one occasion use was made of a string line ray for "tacheometric" shots. Levels were required on the bed of a deep river, 140 ft. wide, and no boat was available (Fig. 19). The theodolite was set up on the bank, and a heavy weight on the end of the string

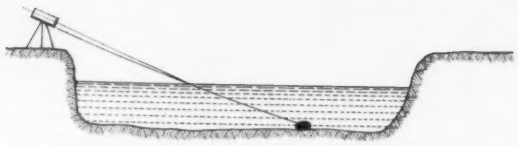

Fig. 19. "Tacheometry" using string ray

line was cast into the river. The line was pulled taut and brought to the instrument, which was used to measure dip and bearing off R.O. to the intersection of line and water. The line was knotted at the instrument and the weight retrieved to measure the distance from the instrument to the point on the bed of the river.

ACKNOWLEDGMENT.—The author is indebted to the North of Scotland Hydro-Electric Board and Sir Alexander Gibb & Partners for permission to write this article, and to A. M. Carmichael Limited, Edinburgh, the contractors for Errochty dam, who supplied information and equipment.

Hydraulics Research Board Report

The Fifth Annual Report,* for 1952, of the Hydraulics Research Board of the Department of Scientific and Industrial Research of H.M. Government refers to continued progress in the design and construction of the hydraulics research station at Wallingford. This station has been established to study problems connected with free boundary hydraulics, such as control of rivers and estuaries, improvements of ports and harbours, and coast protection.

Wave Basin I, which is 125 ft. long by 80 ft. wide and 2 ft. 6 in. deep, and is to be used for investigating wave-cum-tide problems, was handed over for use in June 1952. The 12 ft. wide channel and the 5 ft. wide flume, which are 350 ft. long, 2 ft. 6 in. deep and to be used for basic research into the effect of discharge and charge of material on the regime shapes and slopes of channels, were also handed over in June. The construction of Wave Basin II, which is of the same dimensions as Wave Basin I, but in which coastal currents can also be reproduced, has been completed, but at the time of the Report was awaiting the delivery of a large reversible circulating pump.

A general-purpose wave tank, 10 ft. wide and 54 ft. long, which will be used to investigate the effect of various designs of coastal walls on beach erosion, and a 2 ft. wide wooden flume, were both completed early in the year and experiments are proceeding in them.

The workshops and service laboratories became available in September, and machine tools and other facilities have been installed and are now in use. Work has started on the main model building, in which models will be housed. Stage I will comprise an area of 300 ft. by 200 ft., the roof being supported by columns spaced 100 ft. apart.

Tidal model investigations have been in progress in connection with the estuaries of the Thames and Wyre, and with an idealised estuary. Work on the large Thames model, being carried out by the Port of London Authority on the advice of the Director, was aimed firstly at proving the model, secondly at investigating proposals for excluding silt from the Surrey Commercial Docks by means of a weir, and thirdly at investigating the causes of siltation in the Tidal Basin at Tilbury Docks. After a preliminary model study of the flow conditions in and around Tilbury Basin, one section of the model was reconstructed as a part-width model of the Tilbury area to scales of 1/120 : 1/60, and experiments are now in progress, accompanied by field observations.

A study has been made of the movement of shoals and channels in Morecambe Bay at the request of the Railway Executive, who feared that the approaches to Heysham Harbour might cease to be navigable at low water if the present apparently progressive reduction in depth were to continue. A detailed analysis of the surveys made between 1845 and 1941 showed that the area is subject to cyclic changes and that there is no evidence that Morecambe Bay is silting progressively.

Further model studies have been made of the problems associated with the construction of a weir on the River Eden and with the design of a standing-wave flume for measuring the discharge of Hermitage Stream, Hampshire.

On behalf of the Lyttelton Harbour Board, New Zealand, an investigation has been undertaken into designs for extending the existing harbour, so that at each stage of development the harbour will provide adequate protection from ocean swell. Two models of the harbour have been built in Wave Basin I, and experiments are now in progress on the smaller of the two models which has scales of 1/600 : 1/100. Both waves and tides are being reproduced.

An experiment has been carried out in the 54 ft. by 10 ft. by 3 ft. wave tank to determine how the rate at which water particles drift in the presence of waves varies with depth. This experiment has yielded interesting results.

A survey and research section has been organised, and started work this year on beaches in the neighbourhood of Hurst, Christchurch, Bournemouth and Poole with the object of collecting data on coast erosion. Much of this first season was devoted to the development of working techniques and to learning the capabilities and limitations of such a group, and valuable experience was gained.

* "Hydraulics Research, 1952." H.M. Stationery Office. Price 6s. net.

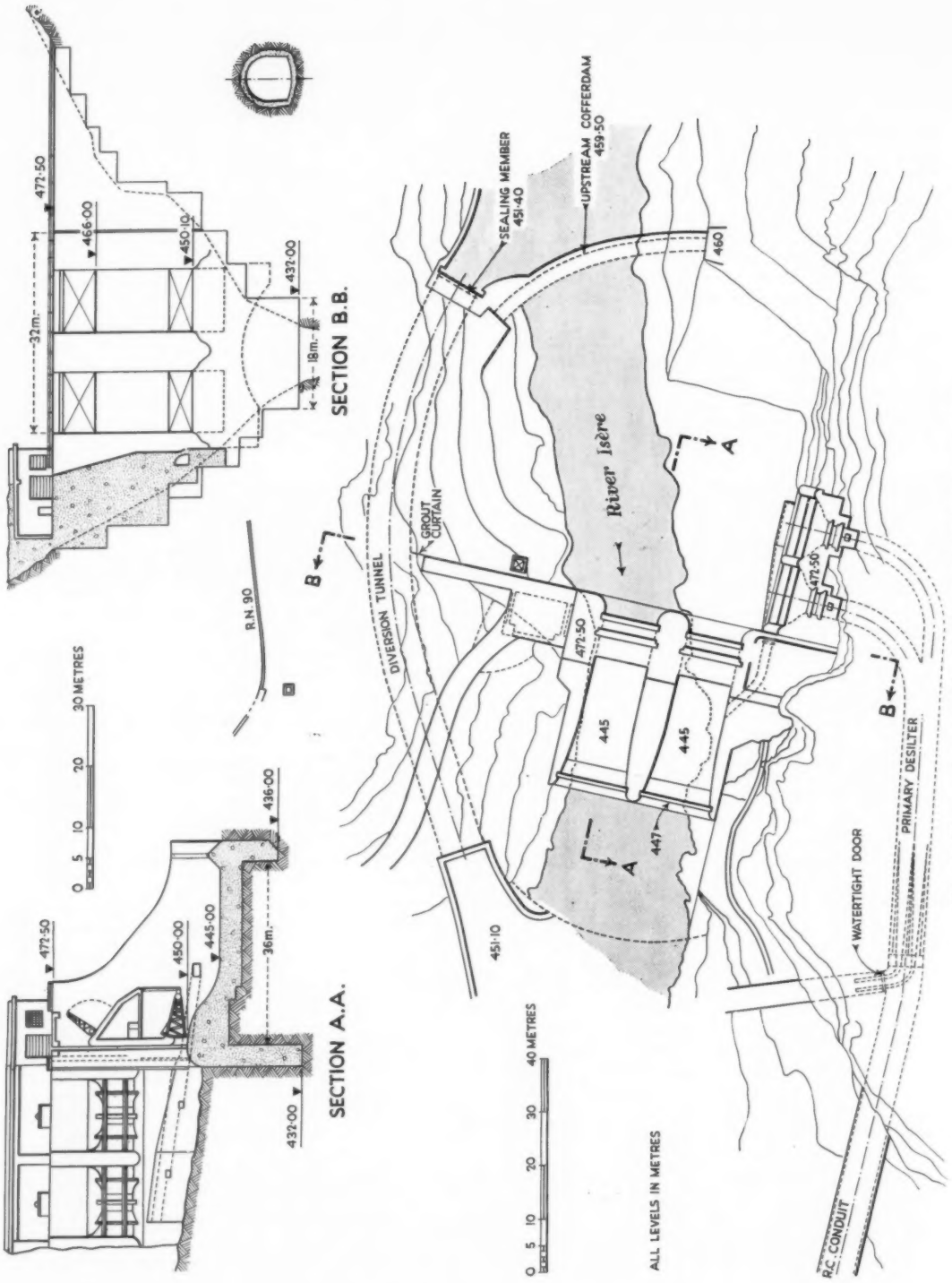

Fig. 1. Plan and sectional elevations of the intake structure

THE ISÈRE-ARC DEVELOPMENT

The Isère-Arc Development

A description of one of the important projects of Electricité de France, with special reference to the design of the dam, surge chamber and pressure shafts

By DR. CHARLES JAEGER

PART ONE

THE River Isère, between the town of Moutiers and the junction with the Arc River, forms a large loop, 45 km. long, with its apex at the town of Albertville (Fig. 1). The maximum total head is 153 m., the area of the natural catchment basin is 1,575 sq. km., with, later on, an additional 120 sq. km. through water diversion at Roselend; the average natural discharge of the Isère River at Moutiers is 50 cu. m. per sec.* However, the Tignes dam†, with its 235 million cu. m. capacity reservoir, which is now nearing completion, and the future reservoir which is to be constructed on the Doron de Bozel, at Champagny, will eventually increase to a considerable degree the minimum discharge of the Isère. Consequently the Isère-Arc tunnel has been designed for 100 cu. m. per sec., corresponding to the discharge available at Moutiers during the winter peak hours. The installed capacity of the Isère-Arc development will be 140,000 kVA, and the estimated average yearly output is 450,000,000 kWh.

* P. Chapouthier and M. Kobilinsky: "Isère-Arc Development (Randens Power Station)." *Travaux*, Paris, Vol. 35, No. 195, January, 1951.
† See Ch. Jaeger: "A Study Tour in the Alps," WATER POWER, May-June, 1951, and "The Malgovert Tunnel," WATER POWER, July, 1952.

The project is an underground power station comprising the following structures:

A dam 21 m. high, impounding a net volume of 400,000 cu. m., which is nothing more than a compensation basin.

A water-inlet excavated in the rock on the left bank and two pressure sand-eliminators (Dufour type), installed in straight alignment with the intake conduits.

The pressure conduits, with 32 sq. m. net cross section, 16,200 m. total length, including a circular reinforced-concrete conduit, 6·40 m. diameter, laid across the hillside (length 2,500 m.); a gallery parallel to the Isère River (length 3,000 m.), and a cross gallery under Mont-Bellachat, called the "Main Tunnel" (length 10,700 m.). An adit 1,000 m. long connects the working platform at Notre Dame de Briançon with the junction of the two galleries.

A non-overflow surge tank with restricted orifice (about 15,000 cu. m. capacity).

Two vertical steel-lined penstocks 3·70 m. in diameter.

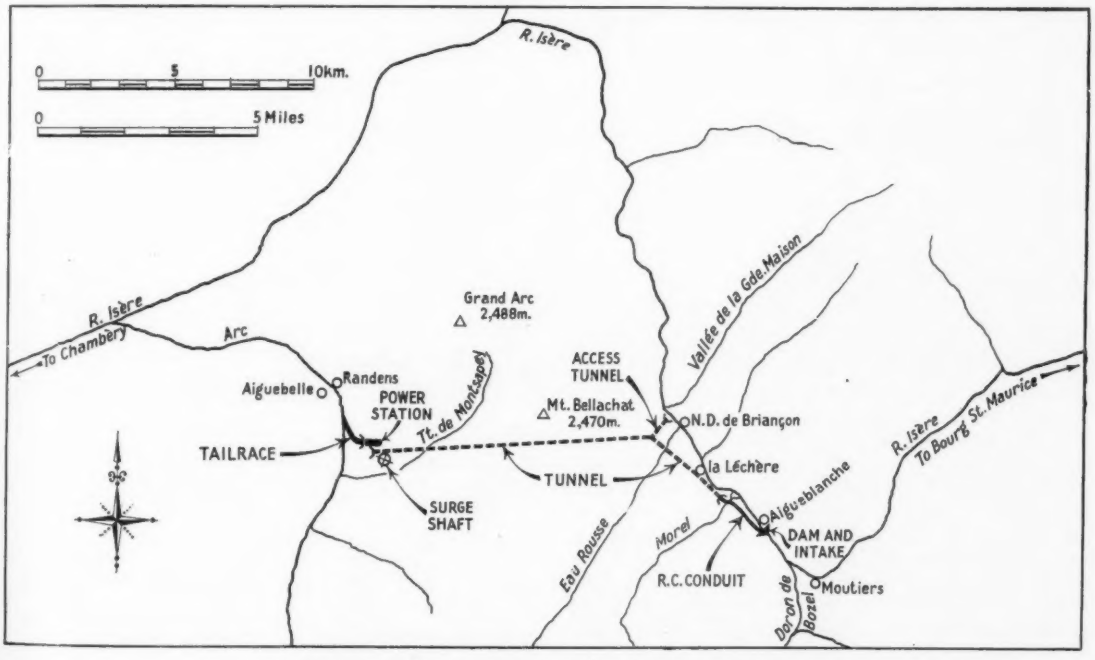

Fig. 2. Locality map of the Isère-Arc development

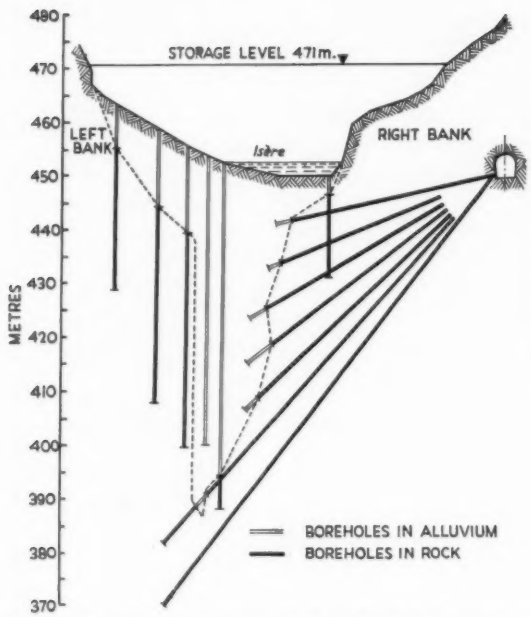

Fig. 3. Transverse section of the alluvial channel at the dam site, showing the system of boreholes

An underground power house containing four 35,000 kVA vertical Francis turbine-generator units and two banks of three single-phase transformers.

A tailrace canal, 1,250 m. in length.

Intake Structures

The dam (reservoir level 471·00 m.) is located at the downstream end of the Pont-Séran gorge, where the bed of the Isère narrows down between two rocky spurs. The soundings have shown the presence of a narrow, deep, alluvial furrow, reaching down to a depth of 70 m. beneath the bed of the Isère River. Measurements had proved that the alluvial formations were impermeable and, in fact, the foundations of the weir were driven, this last summer, to level 443 m. without any noticeable water seepage. The upstream cofferdam consisted of a rockfill dam with a central core formed by pilings, which did not reach down to the foundation level owing to the imperviousness of the alluvia. It was decided that it was not necessary to make good the furrow under the intake dam throughout its full depth, conditional upon the provision of an adequate line of percolation. The design adopted for the dam is similar to that of the Villa di Chiavenna dam on the River Mera, North Italy, designed by the Edison Company‡, and consists of a horizontal cylinder of about 20 m. opening crossing the gorge at level 440 m. (Fig. 3) on which the dam itself is being built. The upstream cut-off goes down to level 432 m. and the downstream cut-off to level 436·00 m. Later on the foundations will be consolidated by grouting.

The cross section of the dam with two large scour gates (Tainter gates) at the bottom, and two tilting gates at the crest, is of the so-called "Verbois type" —also adopted for the dam on the River Mera.

Some complementary explanation can be given here on the Verbois dam. This dam is located on the Rhône, downstream of the Lake of Geneva, and upstream of the Génissiat and Chancy dams. The water from the lake is clean, but a left-hand tributary, the River Arve, brings a great amount of débris into the Rhône. For many years some geologists and scientists have argued that it would never be possible to build the Verbois power station because of the danger of the reservoir silting up rapidly. Further studies brought more optimistic results, and it was then decided that periodical artificial flushing with the clean water from the Lake of Geneva would enable the reservoir to be scoured, thus maintaining it free from major deposit, provided the sill of the dam were to be at river bed level and not higher. The river bed

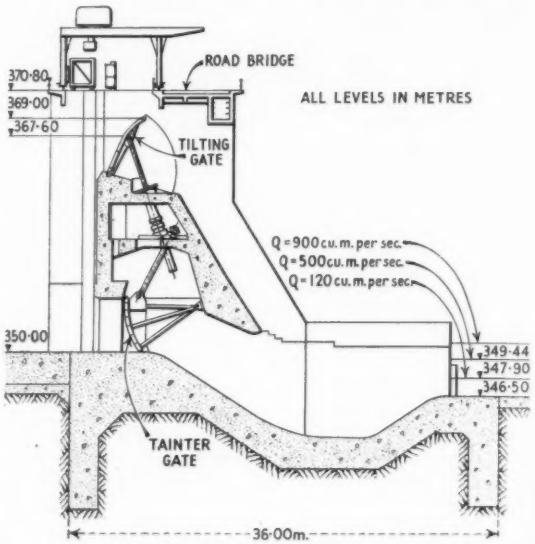

Fig. 4. Cross section of the Verbois dam. This prototype inspired the design of the Mera dam in Italy and of the Isère-Arc dam. Comparison should also be made with the Wettingen dam

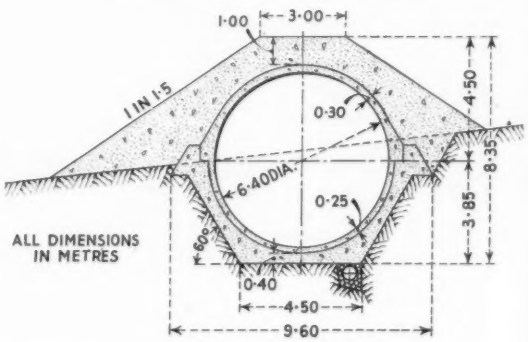

Fig. 5. Cross section of the upstream pressure conduit

‡ See Ch. Jaeger: WATER POWER, June, 1951, Figs. 13, 14, pages 216 and 217.

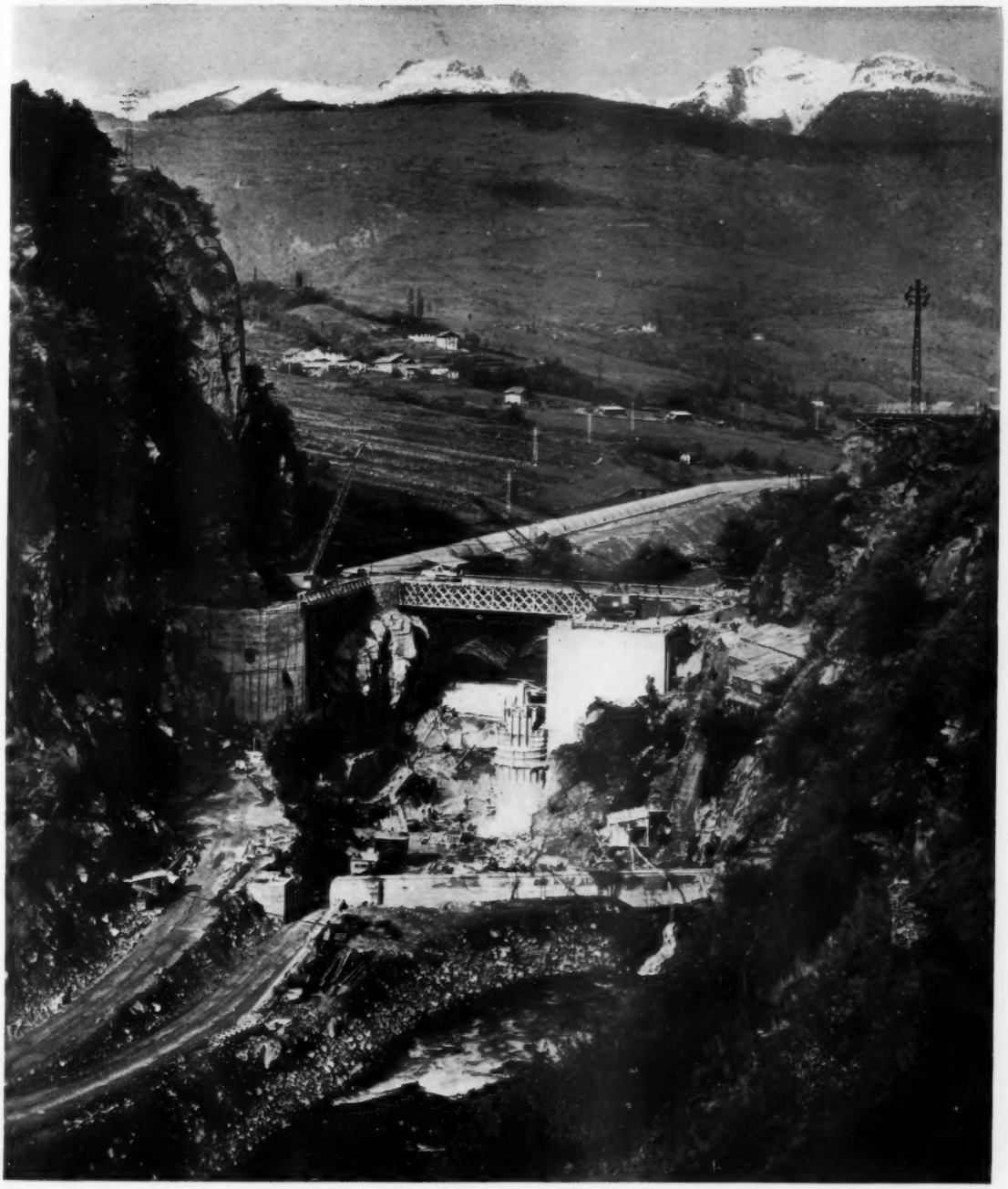

Fig. 6. The dam site in the summer of 1952, seen from upstream. The River Isère is diverted to the right, and the concrete wall will be noted on top of the cofferdam. The two dam abutments can be seen with the outlet of the scour channel on the left. In the background can be seen the beginning of the pressure conduit

of the Rhône downstream of the dam was to be regulated and dredged in order to make sure that the total load of débris coming from the Arve was transported through the weir and further downstream. The whole problem was solved by model tests combined with calculations of débris transportation.

It seems that a similar method was used for the Isère-Arc dam in order to ascertain that the yearly load of débris transported by the Isère would pass the sill of the Isère dam without danger of silting up the reservoir.

This question of silting of reservoirs was one of the main questions submitted to the Fourth Congress on Large Dams at New Delhi (1951). Cases were

described where large reservoirs were totally ruined by silting up. The example of Verbois was mentioned there as a possible solution for the disposal of transported silt and débris.

The writer submitted drawings and proposals to the New Delhi congress.*. It was shown how the same basic principles could be used to drain and flush larger reservoirs, protecting them against possible destruction by silt deposits. The Isère-Arc dam and the dam on the River Mera are other modern exampies of how débris transportation can be dealt with successfully.†

Pressure gallery

The upstream part of the pressure gallery is a circular reinforced conduit, 6·40 m. internal diameter, and 2,549 m. long, laid across the hillside. The cross-sectional area is 32·17 sq. m., the area of the reinforced-concrete section of the pipe is 5·70 sq. m. (thickness 0·25 to 0·30 m.); 1,450 kg. steel reinforcements are being used per metre length. Figs. 5 and 6 give all the necessary information on this part of the gallery.

Fig. 7. The main tunnel after concreting. Note the railway tracks and the large ventilation duct

Main Tunnel

The designers of the 10,700 m. main pressure tunnel were faced with their own problems. The tunnel has a total cross section of 41 sq. m. and is of horseshoe form. The inside net cross section, after concreting, is 32 sq. m. The tunnel is concreted throughout. At least 6 km. will have to be drilled from each end, and from the upstream end work will proceed downward from the end of the adit, because of the uniform tunnel gradient (1·3 per thousand).

The temperature of the rock will attain as much as 37°C. according to experience gained when blasting large trans-Alpine tunnels (Simplon, Mont Cenis, etc.). Drainage of infiltrated water and ventilation are important problems. Ventilation is ensured at each end by two 180 h.p. fans and a pipe 1 m. in diameter delivering 12 cu. m. of air per second for a distance of 6 km. For the drainage, pumps discharging 0·5 cu. m. per sec. are provided at the upstream end. In order to overcome the untoward effects of the phenomenon known to miners as rock bursts (i.e. spontaneous rock explosions due to stress relief in prestressed rock under very high overburden, as en-

* Fourth Congress on Large Dams, New Delhi, 1951, Transactions, Vol. IV, Question 14, p. V-VIII.

† Compare these solutions with the intakes of Lavey and Donzère (WATER POWER, January, 1953).

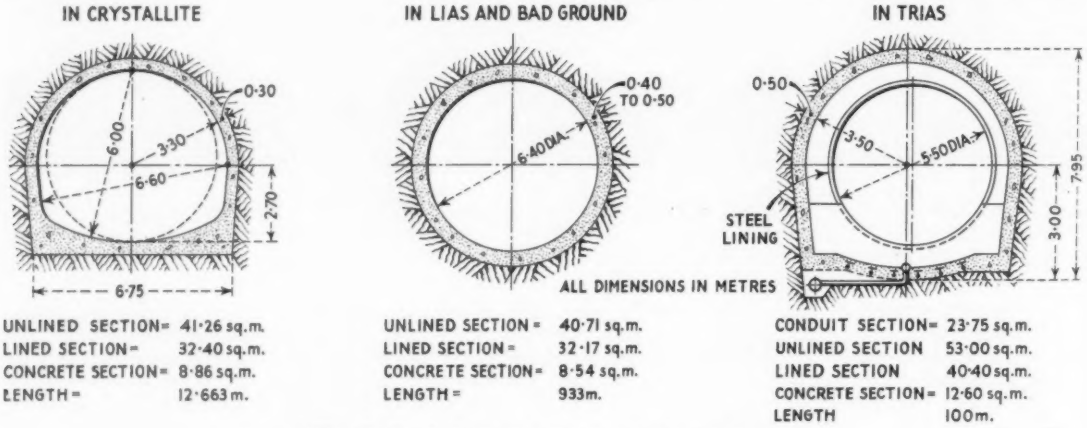

Fig. 8. Typical cross sections of the main tunnel

Fig. 9. The upstream pressure conduit under construction

countered in most of the large trans-Alpine tunnels) a quick follow-up with the concrete lining is necessary.

In all previous trans-Alpine tunnels the method used for excavation was the conventional one involving a pilot drift followed by lateral widening to full section. In contrast with that method, the Isére-Arc tunnel is being blasted to the full cross section whereever the quality of the rock permits. The chief advantage of this procedure is that it offers the possibility of using powerful equipment for removing the spoil, thus enabling the work to be accomplished with reduced manpower, while the workers are required to develop less physical effort in an over-

Fig. 10. View from the tunnel heading showing the two Conway shovels in operation

heated and damp trans-Alpine tunnel atmosphere.

Drilling is carried out from a two-storey jumbo platform, running on a 4 m. wide runway; 14 light-weight hammer drills, with pneumatic pushers and Coromant drill-bits are used. The holes are 3 m. long. The blasting pattern includes 75 drill holes with a fan-shaped plug. The shots are fired electrically with ten delays.

The spoil is loaded by two Conway 75 electric shovels (80 cu. m. per hour peak capacity and 40 cu. m. per hour commercial capacity), into 4 cu. m. Austin-Western tip wagons. Whenever possible the shovels work in parallel. The train of wagons is drawn by 10 ton electric loco-tractors (1 m. gauge), equipped with both battery and trolley pick-up. All rolling stock is 1 m. gauge. Four lines of 30 kg. rails are laid at 1 m. spacings to form—according to requirements—either two side tracks or one central track passing under the jumbo when the latter is withdrawn.

By using the full-section method of advance with the above-described equipment, it has been possible at the downstream heading to make weekly average advances of 9 m. a day, corresponding, approximately, to 3 m. per eight-hour shift, divided as follows:—

Drilling, charging and blasting ...	2 hrs. 40 min.
Ventilation	20 min.
Spoil removal	4 hr.
Laying track and placing the jumbo	30 min.
Miscellaneous	30 min.

The invert lining is being executed after drilling, as the equipment is being withdrawn. It is contemplated to line the sides and the roof at a distance of 500 to 1,000 m. from the heading.

(To be continued)

British-built Euclids for Burma. Blackwood Hodge have secured a £600,000 contract for 40 Euclid tractors and scrapers and a fleet of Euclid rear-dump wagons to be used on the Burmese Irrigation Department's Yemathin District project. Work on this great scheme, involving the construction of a series of nineteen dams, commences next year and will take three years to complete.

"Dominion Engineer." Volume XX, No. 1, 1953, of this journal published by Dominion Engineering Co. Ltd., is devoted to an account of the work of the Hydraulic Division of this famous Canadian concern. The text is liberally interspersed with impressive photographs of Francis, propeller and impulse turbines, pumps, valves of all types, and Michell bearings. Reference is also made to the hydraulic and cavitation laboratory which will be described more fully in a future issue of *Dominion Engineer*.

Portable Air Compressors. A leaflet has been published by Holman Bros. Ltd., Camborne, England, describing a stationary two-stage air compressor with a closed-circuit cooling system for situations where a constant supply of water is not available.

Fig. 1. Lower McArthur Falls at the outlet of Lac du Bonnet

The McArthur Development

Although lacking much of the glamour associated with larger hydro-electric power projects under way in Canada today, the McArthur power development of the Manitoba Hydro-Electric Board does present many interesting features

By J. R. RETTIE

THE power station for this scheme is located on the Winnipeg River approximately sixty miles north-east of Winnipeg at the only remaining undeveloped site on this river in Manitoba. In this respect it marks the beginning of the end of an era of far-sighted development of the power resources of a river to the great benefit of the economy of the Province as a whole.

Despite the very low head available, 23 feet, the enormous flow of the river and the fact that it is regulated justify the erection of physically large hydraulic structures and equipment. The installation planned comprises eight 10,000 h.p., fixed blade, vertical shaft, propeller-type turbines directly connected to 8,500 kVA generators. The units are spaced on 58 ft. centres and the turbine runner and generator rotor outside diameters are 17 ft. and 22 ft. respectively.

Close coupling of the turbines and generators and the utilisation of umbrella-type generators has reduced the number of shaft bearings and facilitated the omission of the usual power-house superstructure. The units are enclosed in a relatively low structure above which an outdoor gantry crane operates to provide lifting facilities through hatches, the removable covers to which are situated immediately above each of the eight generating units and above the erection bay at the west end of the power-house substructure. Intake, draught tube and sluiceway stop logs will be handled by a truck mounted crane.

Power will be generated at 6·9 kV and conducted in a metal enclosed bus to an outdoor switchyard on the west bank of the river, where it will be transformed to 110 kV and fed into the provincially owned Winnipeg Electric Company's transmission system, at present supplied by three other hydro-electric generating stations on the Winnipeg River having a total installed capacity in excess of 500,000 h.p.

Decision to proceed with the McArthur power development was based on the fact that it provided the most economical source of new power supplies within the time available to meet the steadily increasing power demands of the region. Previous schemes on the Winnipeg River have varied in cost from $85 per installed horsepower at Pointe du Bois (1911-26)

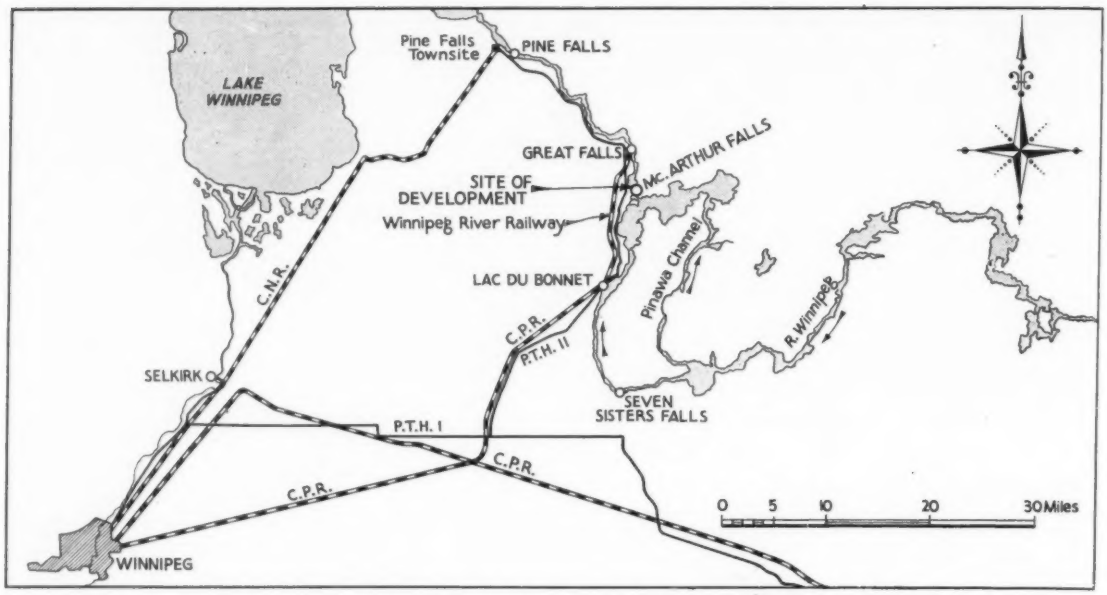

Fig. 2. Location map of McArthur Falls development

to $210 per installed horsepower at Pine Falls (1949-52). It is estimated that the capital cost of developing the McArthur site will be between 22 and 23 million dollars or approximately $285 per installed horsepower. Other potential hydro sites in the province owing to their inaccessibility and size would have resulted in somewhat higher initial development costs.

Steam power was also considered but a study of the integrated capital and operating costs clearly indicated that a public corporation could afford to invest approximately 120 per cent. more in water power and transmission facilities than it could invest in a steam plant and still produce kilowatt hours at approximately the same cost. With capital costs for steam installations currently running in the range of $200 per kilowatt or $150 per horsepower this source of

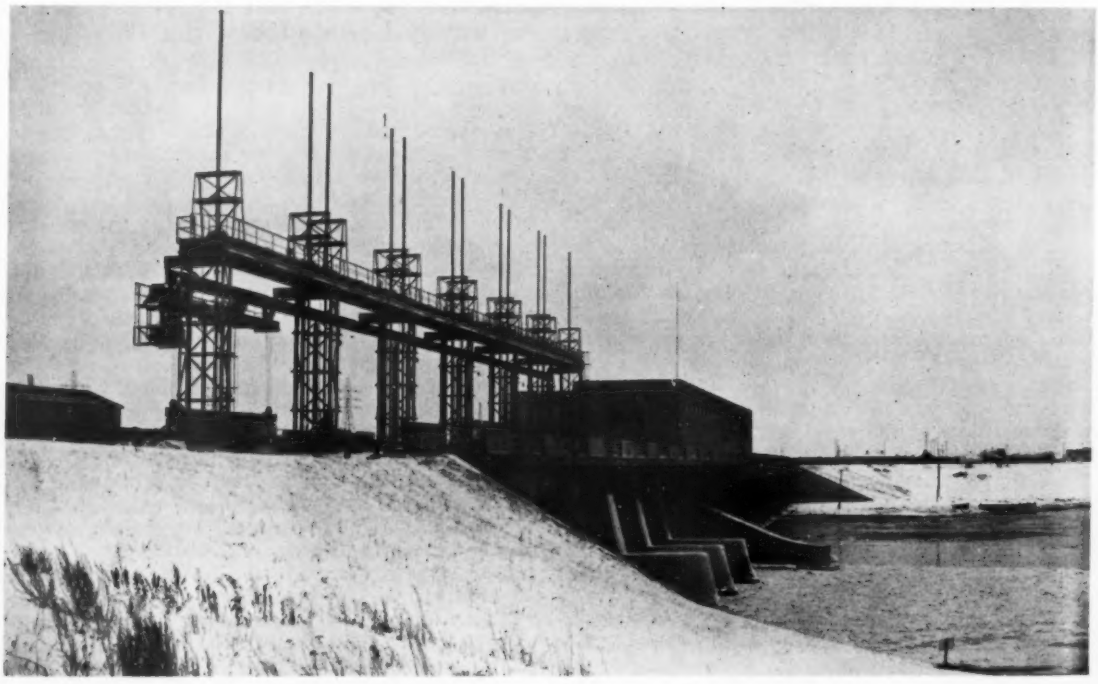

Fig. 3. View of the recently completed Pine Falls generating station

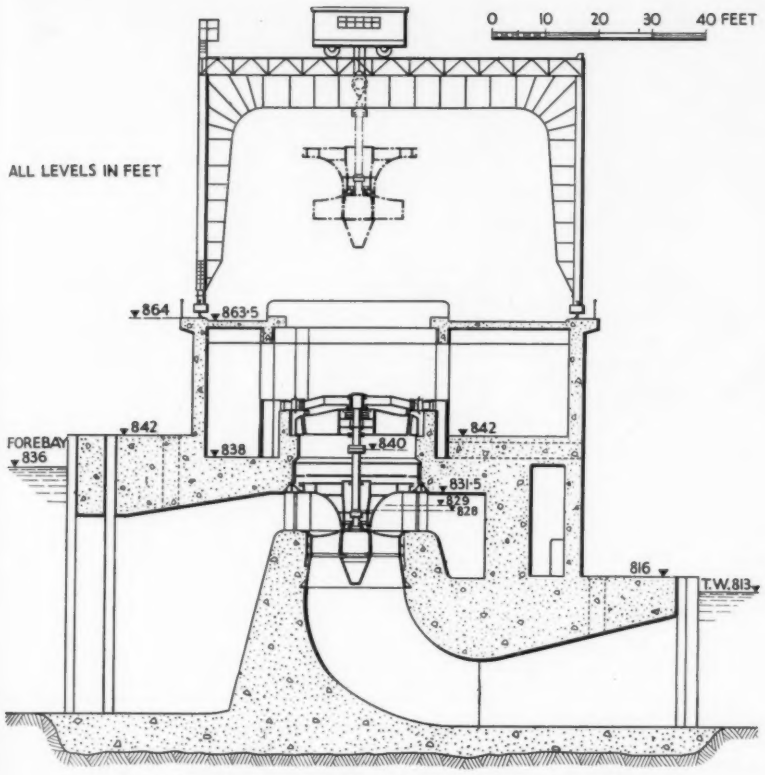

Fig. 4. Typical section through one of the generating units

power was obviously more expensive and furthermore could not be provided in the time required.

The McArthur development is so situated below the outlet of Lac du Bonnet that excellent pondage will be provided with only minor variations in the level of the 47 square-mile forebay. Early engineering studies of this site contemplated a forebay elevation at about the high water level of Lac du Bonnet. In applying for a licence to rights for a 23 ft. head development, the Manitoba Hydro-Electric Board showed that by raising the level of Lac du Bonnet some seven feet above recorded high water level, considerable additional power could be obtained at very little extra cost notwithstanding the payment of just compensation to owners of approximately 250 private properties, the provision of extensive dykes, dyke drainage and bank protection, the relocation of four miles of highway and the raising of several bridges,

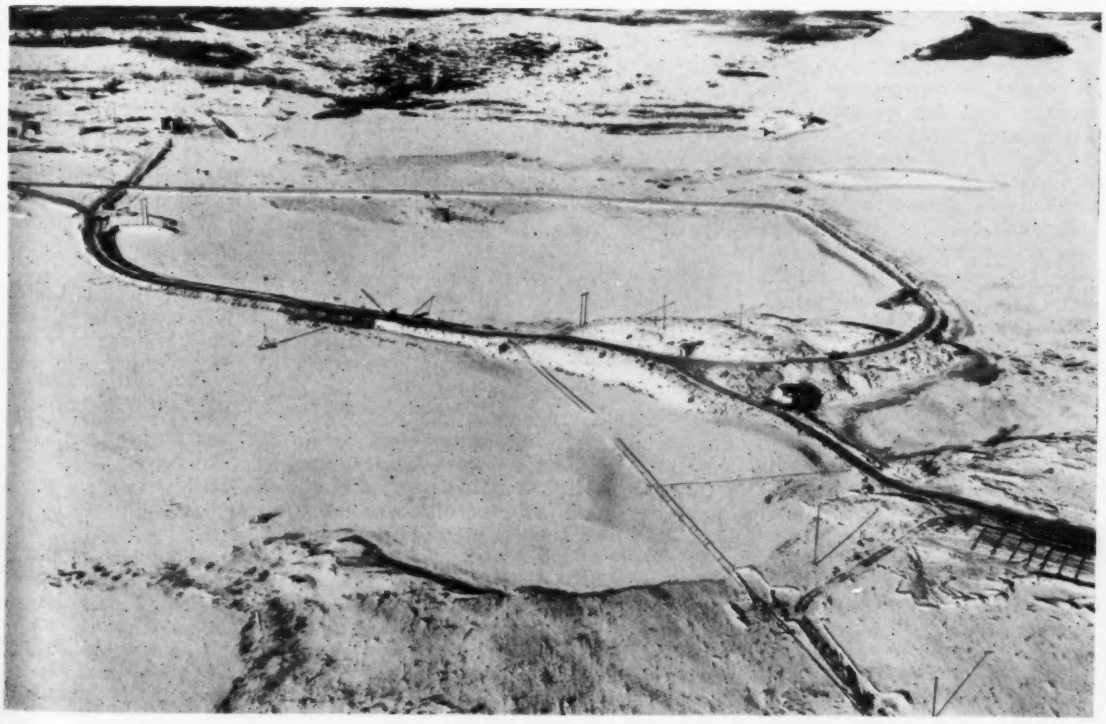

Fig. 5. View taken in December 1952 showing the cofferdam for the power house

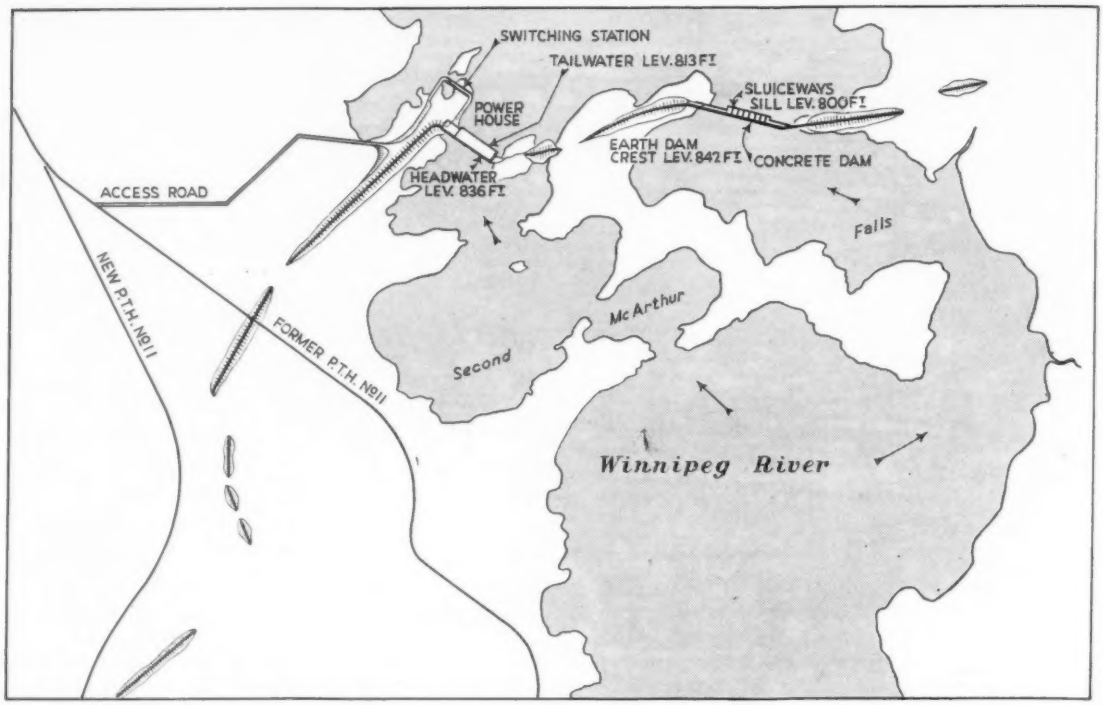

Fig. 6. Plan showing the arrangement of the hydraulic structure

docks and transmission-line crossings. Provision for the foregoing was made possible by the omission of very extensive channel improvements at the outlet of Lac du Bonnet which were an essential part of the lower forebay schemes of development. Further economies were effected by providing an earth dam instead of the conventional concrete gravity dam.

In general the hydraulic structures comprise a reinforced-concrete power-house substructure flanked by short concrete gravity dams, a reinforced-concrete sluice-gate structure comprising eight 40 ft. wide by 37 ft. high cable-hoist type sluice gates flanked on either end by short concrete gravity dams. The foregoing structures are interconnected and flanked by compacted earth dams and dykes totalling approximately seven miles in length and one million cubic yards in volume. Concrete requirements total approximately 130,000 cubic yards and will be produced from crushed granite quarried at the site, and local sand.

Other benefits to the time schedule and costs have been gained by the moving of a complete set of construction camp and job buildings to the site from the recently completed Pine Falls development located 16 miles downstream, as well as provision of drains, roads, highway relocation and railway facilities in advance of awarding a contract for the main construction work.

Active construction by the general contractor commenced early in October, 1952, under a unit-price type of contract and progress to date is on schedule. Cofferdams are of the earth blanketed rockfill type to withstand heads in the order of 30 to 35 ft.

Initial generation from four units is scheduled for the autumn of 1954 with the remaining capacity to be available during the summer of 1955.

Designing and consulting engineers for the project are H. G. Acres & Company, Niagara Falls, Ontario, and the general contractors are the Northern Construction Company & J. W. Stewart Limited, Vancouver, B.C.

Hydro-Electric Generators. A brochure received from Bruce Peebles & Co. Ltd., of Edinburgh, gives concise, illustrated descriptions of the various types of generator they now manufacture to operate with water turbines. Machines are considered up to 24,000 kVA but it is pointed out that the company is now in a position to build larger machines to suit any individual requirements.

Stabilimenti Elettromeccanici Riuniti Ansaldo—San Giorgio, Genova. The fortnightly "Notizario Ansaldo —San Giorgio," published by this well-known Italian concern, now replaces the old monthly "Bolletino Tecnico Ansaldo—San Giorgio." The first issue received (5.12.1952) deals with impulse tests on the winding of electric machines, and also describes the new up-to-date testing plant at San Giorgio di Campi. Short notes, relating to plant supplied by the concern to Argentine and France, are added, followed by an article on the assessment of labour productivity. The illustrations, both black and in colour, are excellent.

Electrohydraulic Turbine Governors. Nydqvist & Holm Aktiebolag have issued a handsome technical brochure to explain the operation of their electro-hydraulic governing gear which was described in our October 1952 issue, page 396. It will be recalled that this equipment produces all the control quantities electrically and uses hydraulic servomotors to provide the necessary power amplification.

Book Reviews

Bort. Special publication of *La Houille Blanche*, Rue Paul Verlaine, Grenoble, France. 368 pp. Profusely illustrated. Price: paper covers 2,000 fr., bound 3,000 fr.

This special publication describing Electricité de France's new development at Bort on the Dordogne is of a quality and exhaustiveness that we have learned to expect from its admirable predecessors, notably "Hydraulique et Electricité Françaises" and "Génissiat." The Bort development is the fourth to be completed on the River Dordogne, and is farthest upstream, the others being at Le Chastang, L'Aigle and Marèges. Two further upstream developments are envisaged at Singles and Chavanon and one downstream at Argentat. The Bort dam has given France its most important storage to date, and will provide valuable regulation to the three stations downstream at times of heavy demand. Some difficult problems had to be surmounted, notably in connection with foundations due to the heterogeneous nature of the terrain, and the techniques employed in this and other parts of the work are of special interest. Of these particular mention should be made of the use of the Trief process for making the concrete, employing wet-ground blast-furnace slag to replace part of the cement content, and of the application of artificial cooling to the concrete.

Every aspect of the planning and execution of the work is described in detail in 17 chapters, each contributed by the engineer particularly concerned.

A word of praise must be added with regard to the photographs and drawings, which contribute notably to the value and interest of the publication.

Importance of Secondary Flow in Guide Vane Bends. By Edward Silberman. Technical Paper No. 14, Series B, January 1953. University of Minnesota, St. Anthony Falls Hydraulic Laboratory, Minneapolis.—Price 35 cents.

Both the paper here reviewed and its predecessors (notably the work by H. B. Squire and K. G. Winter in this country) may appear, at a first glance, to be unduly theoretical. When, however, the practical applications of Mr. Silberman's research are investigated, it will be seen that they relate to several fields of both civil and mechanical-engineering hydraulics as used in the design of water-power projects.

The paper is concerned with flow around bends, whether in closed ducts or in open channels, where guide vanes are used to obtain a nearly uniform velocity distribution downstream of the bend. The use of such guide vanes is complicated by the interaction of the adjacent vanes, and by the appearance of cross currents (secondary flow). As Mr. Silberman states in his abstract, which in itself is a model of conciseness, "the secondary flow has negligible influence on the two-dimensional deflection" of the primary stream, "but the two-dimensional head loss is increased materially by the secondary flow." The larger part of the increase in head loss occurs not in, but downstream of, the bend, and is due to increased wall shear which is, "in turn, attributable to the redistribution of streamlines by the secondary flow."

The results of this work, based on several years of experimental study, will be of especial interest to the designer of guide vanes, turbines and draught tubes, as well as to the engineer concerned with the design of short-radius bends in tunnels, pipelines and open or closed tailrace canals.

International Letter Symbols used in connection with Electricity. International Electrotechnical Commission, 39, route de Malagnou, Geneva. Price 3 Swiss francs.

This, the third edition of I.E.C. Publication No. 27, is the culmination of revision work which was initiated in 1935 but was held in abeyance during the war. All the National Committees have agreed to the publication of this list, which has the form of recommendations for international use, although a few Committees have suggested certain modifications which will need discussion before they can be included. The symbols cover mathematical, space-time, energy, mechanical, thermal, electric, and magnetic quantities, and are arranged both under these headings and also alphabetically. French and English texts appear on facing pages throughout.

A Coronation-Year Souvenir. As a Coronation-year souvenir, Painter Bros. Ltd., Hereford, who specialise in overhead-transmission towers, radio masts, and similar structures, have prepared a brochure giving a map of the recommended route from London to Hereford. The unique feature of this publication is that it is presented in the style adopted in 1675 by John Ogilby, Cosmographer to King Charles II. It consists of two illuminated plates, covering London to Witney and Witney to Hereford respectively, showing the route as if inscribed on a scroll. A title plate includes the coats of arms of the counties through which the road passes, and the whole is enclosed within black covers tied with red cord. Artist, cartographer and printer have combined to produce a beautiful souvenir.

The Harland Engineering Co. Ltd., 1903-1953. Under this title this well-known Alloa concern has published an interesting brochure outlining the history of the company during the fifty years of its existence and showing its present position by means of financial statements and coloured diagrams. The company has consistently followed the policy of allowing customers' demands to indicate the line of development, and this is well evidenced by its wide range of manufactures, including water turbines and alternators, pumping plant, generators, electric motors, and specialised productions such as the Harland paper-machine drive.

B.I.C.C. Coronation Souvenir. An acceptable coronation souvenir has been presented to us by British Insulated and Callender's Cables Limited in the form of a folding map of London. On one side of the sheet is a road map extending from Windsor to Tilbury and from Cheshunt to Coulsdon, and on the other is a road map from Notting Hill Gate to Wapping and an inset map of the central area. Ministry of Transport road numbers are included on the one map and a key to nearly 200 places of interest on the other.

Pitlochry Dam and Power Station. The March issue of *Wimpey Technical Digest*—an information sheet issued to the staff of George Wimpey & Co. Ltd.—contains an interesting account of this station with special reference to the construction of the cofferdam, the cut-off, foundations, and the methods used in the erection of the dam and power house.

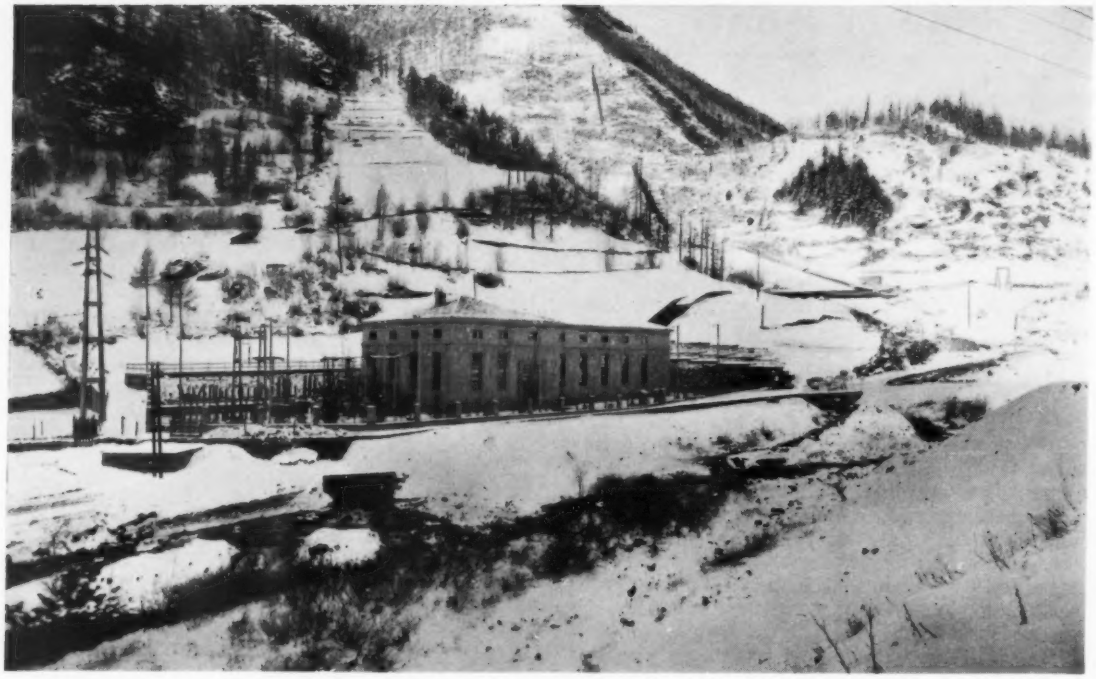

Fig. 1. Exterior view of Fenestrelle station

Fenestrelle Automatic Station

By DANIELE FABRIZI

TECHNICAL DIRECTOR, "SACE", BERGAMO, ITALY

The automatic synchronous station of the RIV at Fenestrelle utilises the waters of the Val Chisone and has an annual output of 42,000 MWh, of which 12,000 MWh are produced during winter. The equipment consists of two horizontal-shaft alternators carrying a Pelton turbine at each end and rated at 8,400 kVA, and the energy produced is transmitted over a 70 kV line to the works of the RIV.

THE automatic station at Fenestrelle was inaugurated last year in the presence of a large gathering. It was built by the Societa RIV, Turin, and constitutes the first link in a complete chain of stations, at present in the design stage, which will utilise the entire hydraulic resources of the Val Chisone. The building, of sober and functional design (Fig. 1), lies near Fenestrelle, close to the road leading to Sestrière. It houses the generating sets, the 6 kV equipment, and below the control room the low-voltage gear for the auxiliary services. The sets are installed in a large rectangular hall (Fig. 2) with their shafts parallel to its longer side. At one end of the hall are the operating and control panels, arranged on a raised platform (Fig. 3). The living accommodation for the station operator lies along the shorter side of the hall. The 70 kV equipment and the step-up transformers are, however, situated in front of the building in a large switchyard (Fig. 4); a transmission line 26 miles (41·655 km.) long leads to the Stella substation at the SIP plant while the feeder to the RIV works branches off after the first 13¾ miles (19 km.).

The station draws on the rainfall area of the upper valley which comprises approximately 52 sq. miles (134 sq. km.) and provides a mean annual flow of 65 cusecs (1,850 litres per sec.), that is approximately 1·25 cusecs per sq. mile (13·7 litres per sq. km. sec.). The mean annual output is estimated at 42,000 MWh, of which 12,000 MWh will be available in winter; the discharge varies between 185 and 39 cusecs (5·25 and 1·1 cu. m. per sec.) at a mean head of 933 ft. (280 m.).

Hydraulic Installations

The dam (Fig. 5) consists of a ribbed wall of reinforced concrete in the central section, flanked by

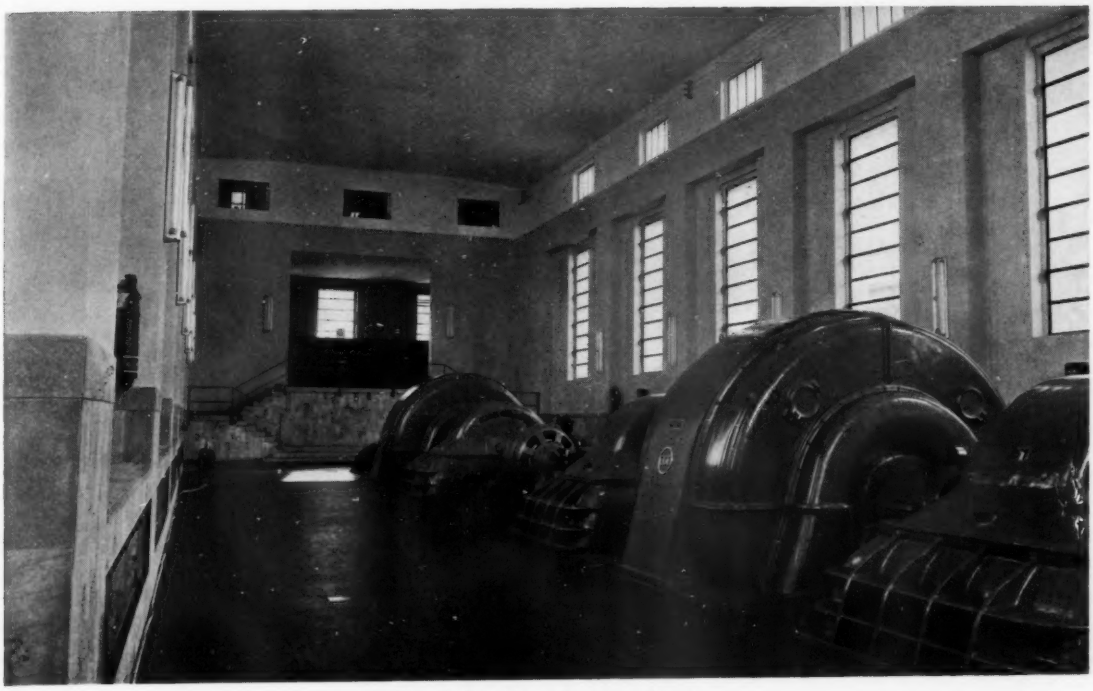

Fig. 2. Interior of power house

concrete-lined embankments; it provides a weekly storage of 10·5 million cu. ft. (300,000 cu. m.). The dam contains two electrically operated gates which were supplied by the Officine Galileo. The central sector gate measures 27×8 ft. ($8 \times 2{\cdot}50$ m.), while the intake is controlled by a flat gate 7×10 ft. (2×3 m.) which acts as a sand trap. With the gates closed, the water level reaches an elevation of 4,640 ft. (1,392 m.).

The intake works, on the right-hand bank, consist of a $9 \times 4\frac{1}{2}$ ft. ($2{\cdot}60 \times 1{\cdot}35$ m.) entry protected by screens; this is followed by a gate leading into a settling basin $167 \times 23 \times 4\frac{1}{2}$ ft. deep ($50 \times 7 \times 1{\cdot}35$ m.). The pressure gallery which starts from here is formed by two tunnel sections 6,800 and 6,000 ft. (2,050 and 1,800 m.) long, joined by a central part, 1,300 ft. (400 m.) in length, which consists of a false tunnel and an overhanging part. The central section has a circular cross-section 6 ft. (1·80 m.) diameter while the end tunnels are of oval shape and measure 64×80 in. ($1{\cdot}60 \times 2$ m.). The tunnel is lined throughout in concrete, but the sections above ground, the false tunnel and the part running through a moraine are constructed as a reinforced-concrete pipe. The maximum flow through this intake gallery is 185 cusecs (5·25 cu. m. per sec.).

The surge tower consists of a vertical shaft lined with reinforced concrete, 130 ft. (40m.) high and 10 ft. (3 m.) diameter at the base. At its upper end the diameter is increased to 17 ft. (5 m.), thus forming an expansion chamber.

The penstock starts at the surge tower; it is 2,460 ft. (740 m.) long and varies in diameter from 52 to 50 in. (1·30 to 1·25 m.). It is run above ground for the whole of its length and is supported on nine foundation blocks. Its sections are riveted both longitudinally and transversally and carry angle-iron reinforcements at suitable spacings to take up the stresses due to pressure surges. Near the station the penstock divides into four branches, each terminating in a spherical rotary valve with a clear diameter of 24 in. (600 mm.) upstream and 21 in. (525 mm.) downstream; they are controlled either remotely or by hand.

The discharge from the station is returned by a short canal to the bed of the Chisone river.

Machinery

Each set (Fig. 2) consists of a CGE alternator driven by two Pelton turbines constructed by Franco Tosi. The turbines have single jets and are fitted with jet deflectors and slowly closing spears for automatic speed control. The constant-oil-pressure governors are provided with air vessels and are sensitive to both the speed and the acceleration of the set.

The details of the Tosi turbines are as follows:—

Nominal power	6,350 kW
Discharge	94 cusecs (2·66 cu. m. per sec.).
Speed	500 r.p.m.
Average net head	933 ft. (280 m.).

The alternators have been supplied by CGE to the following specification:

Nominal continuous rating	8,400 kVA
Voltage	6,000 V
Frequency	50 cycle
Runaway speed	910 r.p.m.

To ensure satisfactory governing of the sets, a moment of inertia of 850,000 lb. ft.^{2} (35 tons m.^{2}) had to be provided in the rotor of each machine.

Each set includes a main exciter giving 50 kW at 110 V, as well as a pilot exciter.

The machines are cooled on the open cycle, with the air intake and discharge outside the station. There is, however, provision to admit part of the hot air into the power station through suitable louvres along

one of the long sides of the building.

The bearings on both the alternator and the turbine are provided with automatic ring lubrication and are cooled by water circulation.

The forged-steel shaft is flanged to permit direct attachment of the two turbine runners; it has projections which carry without intermediate spacers the magnetic circuit consisting of five forged-steel rings which support the laminated poles in T-shaped slots.

The frame and base are welded up from steel plate.

The stator has a short-pitch double-layer winding. The separate phase windings are arranged in star, but the star point ends are brought out through terminals so that the current transformers for the differential protection can be inserted there.

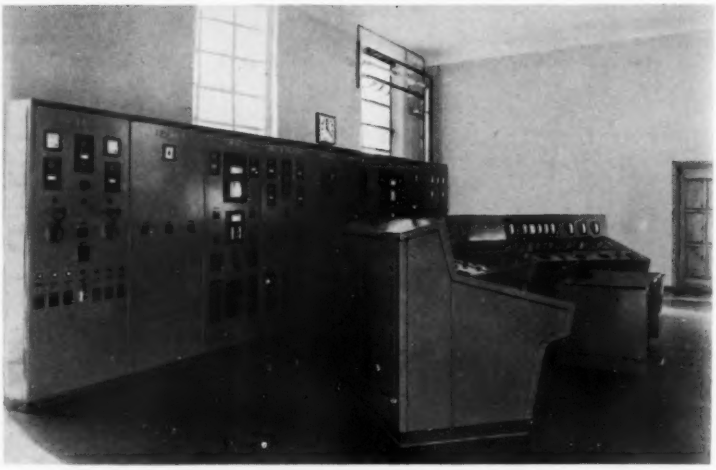

Fig. 3. Metering panels, control panels and desk

The rotor winding consists of bare copper strip wound on edge, insulated with asbestos, and carefully arranged so that some of the turns project, thus ensuring more efficient cooling.

The two transformers (Fig. 4) have been supplied by TIBB. They are of the outdoor type, rated at 8,400 kVA for 6/66 $\pm$ 3 kV, 50 cycles, and connected star-delta.

The transformer core has three limbs joined by two yokes with interleaved joints, and consists of 0·014 in. (0·35 mm.) thick low-loss laminations insulated with paper and suitably offset from each other. The concentric windings are formed from copper strip insulated with high-grade paper. The primaries are connected in delta and provided with three tappings in order to obtain a variation of $\pm$ 3,000V on the secondary side with constant primary voltage. The tappings are arranged symmetrically with respect to the midpoint of the winding on each limb so that tap changes will not upset the symmetry of the operating turns relative to the midpoint. The tappings are connected to the tap-changer gear which

Fig. 4. Outdoor high-voltage equipment

Fig. 5. Intake works and dam

is mounted inside the tank and operated from the outside by hand while the transformer is de-energised. The insulation between the primary and the core consists of a cylinder of bakelised paper; the two windings are insulated from each other by oil-impregnated paper whose ends are folded over to form a number of flanges separated by several thicknesses of insulation.

Each transformer is fitted with an oil reservoir. The tank is so designed that the gas bubbles are collected and led towards the pipe to the expansion vessel; this ensures more reliable operation of the Buchholz protective equipment.

The transformer tank is made from smooth steel sheet; there is provision for creating inside it the vacuum required for drying out the oil. Cooling is effected by forced circulation of the oil which in turn is cooled in a water cooler with a capacity of 45 g.p.m. (200 litres per min.). The hot oil is withdrawn from the upper part of the tank by an electric pump whose delivery pressure is greater than the cooling-water pressure, thus preventing any leakage of the latter into the tank in case of damage. The cooling equipment also includes indicators for the water and the oil circulation. Each transformer is fitted with a dial-type thermometer indicating the oil temperature; it is provided with two contacts, one for the alarm and the other for the automatic shut-down circuit.

Metering and Control Board and Equipment

As has already been mentioned, the control board and desk (Fig. 3) supplied by SACE, Bergamo, are placed in a raised position in the machine hall, accessible by two sets of steps. This arrangement has been chosen because it simplifies operation and permits direct supervision of the machinery. The board (Fig. 6) runs parallel to the end wall in which there are three large windows, giving ample illumination of the room. It consists of nine panels of exceptionally simple and elegant design, made from $\frac{1}{8}$ in. (3 mm.) thick sheet steel with beading around the sides. All connections within the control board are made in plastic-insulated wire. The terminals are coloured and are arranged on terminal boards at the bottom of each panel to which the various cables are connected.

The equipment is divided between the board and the control desk by arranging on the latter the actual operating gear, such as for example, selectors, controllers, press buttons, etc., as well as the metering equipment required for direct use. The control board, on the other hand, carries the remaining metering equipment, contactors, the automatic synchronising and paralleling gear, main and auxiliary flag relays, recording instruments, and all the equipment for the auxiliary supplies. Its nine panels run from left to right as follows:—

Panel 1: A.C. auxiliary supplies.
Panel 2: No. 1 turbine.
Panel 3: No. 1 alternator.
Panel 4: No. 1 transformer, 9 kV line.
Panel 5: Synchronising equipment.
Panel 6: No. 2 transformer, 70 kV line.
Panel 7: No. 2 alternator.
Panel 8: No. 2 turbine.
Panel 9: D.C. auxiliary supplies.

The control desk is placed in front of the board (Fig. 7); it is similar to the latter both in the arrangement of the wiring and in its metallic structure (Fig. 8). The shape has been chosen so as to give a functional and at the same time harmonious appearance. It is closed by doors at the back and consists of nine small panels, three of which form the centre section, with two panels at each side set at an angle of 120° to it and joined with it by two further panels of triangular shape.

The panels are arranged from left to right as follows:—

Panel 1: No. 1 alternator governor.
Panel 2: No. 1 alternator.
Panel 3: Centralised controls.
Panel 4: No. 1 transformer, 9 kV line.
Panel 5: Auxiliary supplies; manual synchronisation.
Panel 6: No. 2 transformer, 70 kV line.
Panel 7: Emergency shut-down controls.
Panel 8: No. 2 alternator.
Panel 9: No. 2 alternator governor.

The desk also carries a diagram in different colours into which selectors and controllers are incorporated.

This diagram repeats in schematic form the layout of the station (Fig. 9); it simplifies the different operations very considerably and provides the easiest means for the staff to distinguish between the various control functions. The controllers are of the press-to-operate type and incorporate a signal lamp which lights up when the controller position differs from that of the corresponding equipment, and is extinguished when they agree. Selectors only are provided for the isolating switches, fitted with a light which operates in the same manner.

All the control gear is mounted in a frame in a room underneath the control board which also contains two 150 kVA 6,000/220/127 V transformers supplying the auxiliary services, and a 150 kVA 6/9 kV transformer which links the station to a transmission line of the PCE over which energy can be transmitted in both directions. The 6 kV busbar system with its isolators and switchgear is arranged on the floor below, together with the resistance panels for the voltage regulators. An underground duct leads from here to the alternators and contains the supply busbars. The star-point resistances of the alternators and the earth-fault protection current transformers on the stator are located at the beginning of these busbar ducts immediately below the machines. The "Santuari" de-energising gear is, however, mounted in the machine hall.

Fig. 6. Metering and control board

A 110 V nickel-cadmium battery of 104 cells, with a storage capacity of 100 ampere-hours, is arranged in a separate room.

Automatic and Protective Gear

The complex arrangement of the station, which was

Fig. 7. Metering and control desk

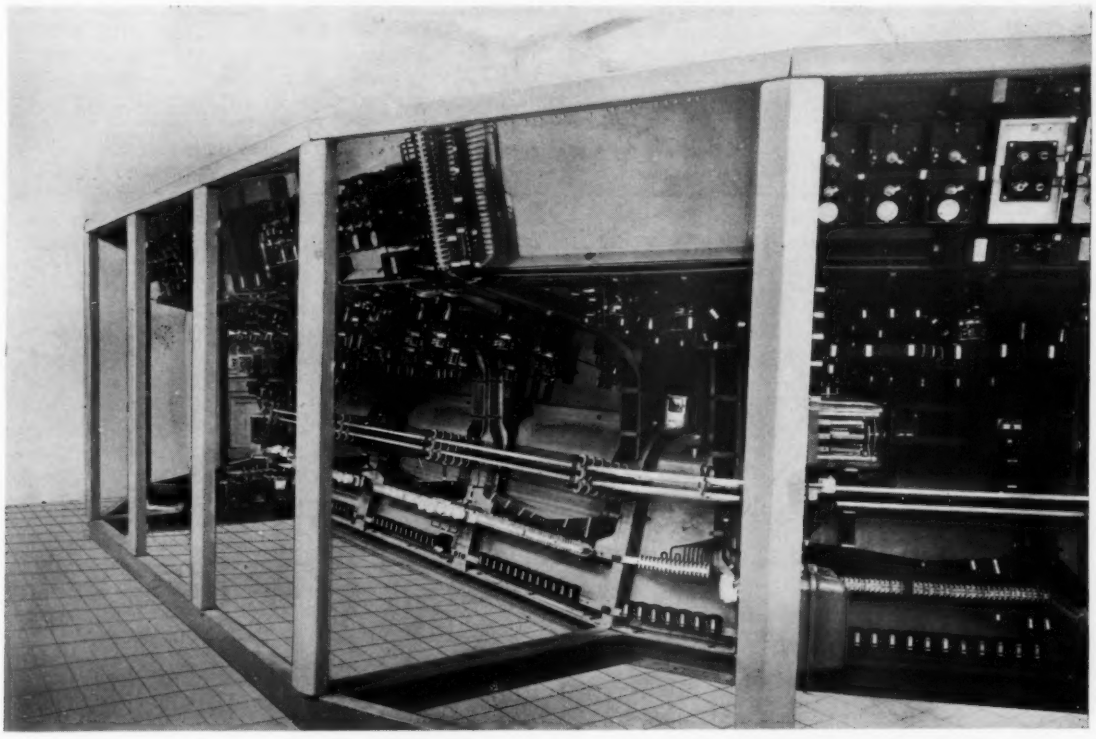

Fig. 8. View behind the control desk showing the connections

designed to meet special requirements, has rendered it necessary to make a detailed investigation of the supervisory equipment, which provides for both manual and automatic operation. The appropriate method of control is selected by a change-over switch. Selectors are also provided for the following operations: deciding the order in which the two sets are started up, excluding one of the sets from the automatic control scheme, and the starting order and exclusion of each of the two runners of a set. With the automatic control gear in operation, the station is controlled completely by pressing a single button. The automatic gear is supplied from a number of d.c. busbar systems whose voltages depend on the type of service. The whole of the automatic equipment is shut down not only by the usual protective gear but also by two no-volt relays on the auxiliary supplies, one for the d.c. and the other for a.c. services. The supervisory gear and the interconnections have been designed by SACE, Bergamo.

Each set is started up from the turbine side, beginning with the energising of the appropriate auxiliary relay. This operation is interlocked with the open position of the field and main circuit breakers, with the inactive positions of the centrifugal and shut-down relays, and with a setting of the load limiter below the starting position. An indicating lamp remains alight during the whole starting-up period until the set is paralleled with the busbars. An auxiliary relay operates an alarm when the starting-up process has not been completed in a preset time.

Operations on the turbine itself start with closing the contactor controlling the electrically driven auxiliary oil pump which supplies the speed-acceleration governor. Once this pumping set is run up to speed, a pressure relay energises the coil controlling either the right-hand or the left-hand inlet valve, depending on the starting sequence selected. At the same time the needle valve controlling the turbine-driven oil pump is opened. As soon as its oil pressure has reached the correct value, the auxiliary electrical pump set is shut down again.

Once the valves have opened an amount determined by a limit switch, the governor and no-load running coils are energised so that the governor is released from the closed and no-load positions and begins to open the jet spear. As soon as the latter has reached its starting position, the no-load running coil is again de-energised so that the governor returns to its no-load position. In the meantime the set has reached approximately its normal speed. The permanent-magnet alternator driven directly from the turbine now begins to supply the tachometer motor of the governor which takes over the control of the set. Once the correct speed has been reached, a voltage relay starts up the paralleling equipment which eventually closes the main circuit breaker after the alternator has been synchronised. At this moment the station operator takes over again and opens the turbine control spear to the setting corresponding to the desired load. The second sets starts up in the same sequence, initiated by the closing of the circuit breaker of the first set.

The automatic voltage control consists of a high-speed regulator with compensated static characteristic; apart from maintaining the voltage at the alternator terminals practically constant, it also controls under

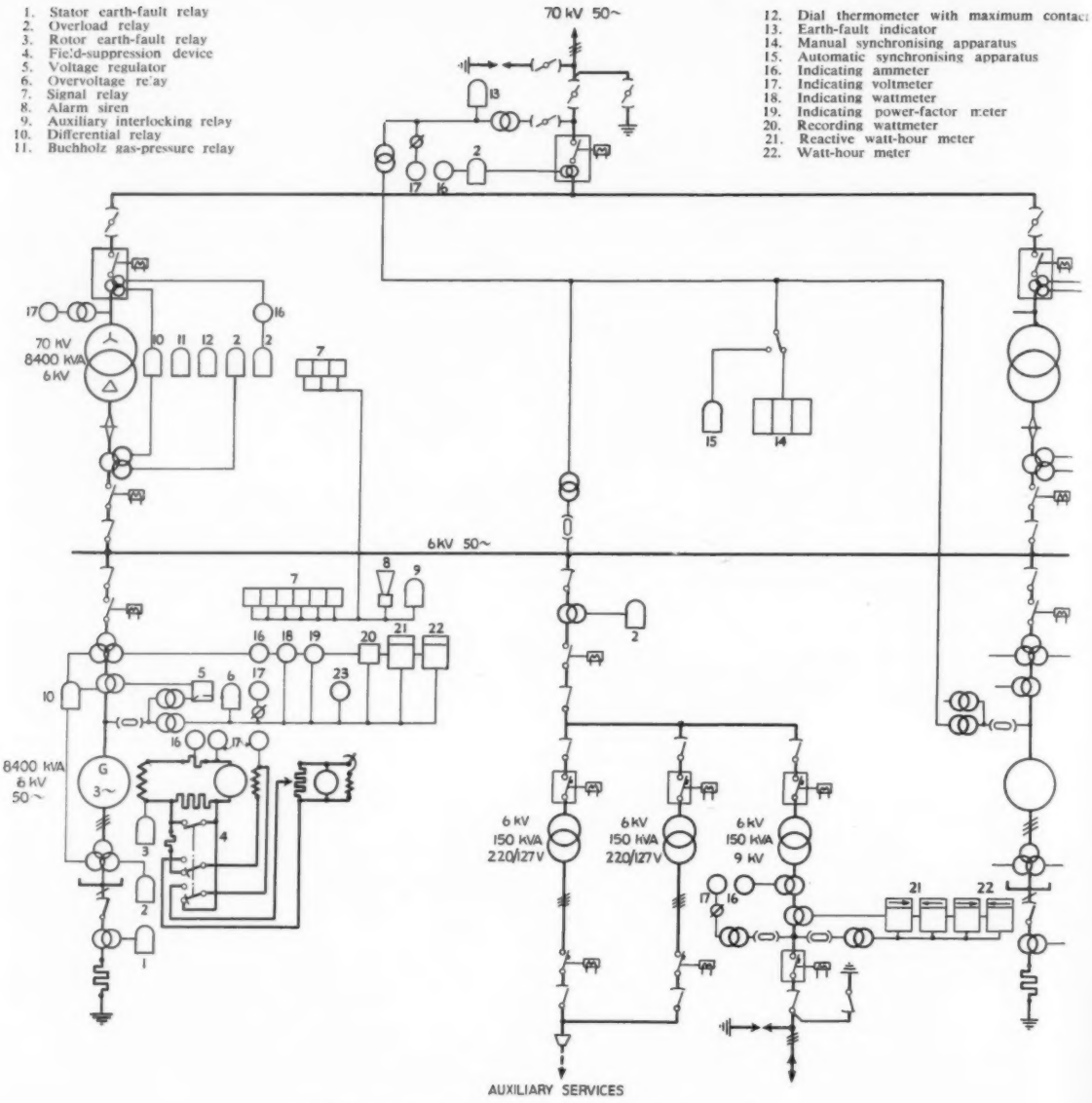

Fig. 9. Single-line diagram of Fenestrelle station

certain definite conditions the distribution of the reactive power between the two alternators in parallel in proportion to the active power load.

The voluntary stopping of the station can take the form either of a complete shutdown with locking in shut-down position, by pressing the appropriate emergency button, or of a normal switching-off operation.

Considerable importance has been attached to the protection of the machinery, and all equipment has been provided which can prevent the disastrous consequences of a disturbance, or reduce them as far as possible.

The protective devices operate either the shut-down with lock-in, or the alarm, depending on the nature of the fault.

THE FOLLOWING PROTECTIVE DEVICES OPERATE THE "SHUT-DOWN AND LOCK-IN":—

Differential protection. Owing to the special arrangement of the station and its complexity, this protection requires two three-phase relays on each set, one for the alternator and the other for the transformer. These relays are of the compensated-ammeter type and operate on any internal fault for which the difference between the torques of the currents compared exceeds a certain amount, called the "characteristic percentage." Its value is 10 per cent. for the alternators but has been increased to 25 per cent. for the transformers to prevent incorrect tripping due to magnetising currents.

Short-circuit protection. To guard against short-circuits that might occur within the station on parts not protected by differential relays and on the 70 kV

transmission line, provision has been made for three-pole inverse-time overload relays, adjustable between 0·8 and 3 times maximum load.

Stator-earth protection. This system consists of single-phase ammeter-type relays with inverse time delay; they operate on any earth fault in the transformer primary, on the 6 kV busbars, and on 90 per cent. of the alternator winding. The only part which still remains unprotected is the last 10 per cent. of the winding at the star point. In view of the relatively small capacitative currents in the station it was not considered necessary to install a very complex protective scheme. The relay is supplied from a 2/20 amp current transformer inserted in series with a resistance at the star point of the machine.

Internal over-voltage protection. Any overvoltages originating within the station itself, due to sudden changes in load or increases in turbine speed, are detected by inverse-time voltmeter-type relays whose operating voltage lies between 95 and 200 V.

Temperature rise on turbine and alternator bearings ("Stop" contacts on thermometer).

Runaway speed protection.

Transformer-fault protection ("Stop" contacts on the Buchholz relay).

Excessive transformer oil temperature ("Stop" contacts on thermometer).

THE FOLLOWING PROTECTIVE DEVICES OPERATE ONLY THE "ALARM":—

Short-circuit protection on the 9 kV line (The relay only trips the circuit-breaker on the transmission line).

Rotor earth faults. Although an earth fault in the rotor winding does not cause any damage by itself, it should be indicated immediately since a second earth fault would produce a dead short-circuit across the part of the winding between the two faults; this would lead to arcing, assymetrical stresses, and vibrations which may seriously endanger the machine. The protective gear consists of a flag relay, an isolating transformer fed from the low-voltage auxiliary supply at 70 V, a full-wave metal rectifier, and a change-over switch for testing or disconnecting the protective gear.

Internal transformer faults (Alarm contacts on the Buchholz relay).

Low oil pressure in the turbine auxiliaries.

Loss of cooling-water circulation in the alternator bearings.

Loss of cooling-water circulation in the transformer.

Excessive transformer oil temperature (Alarm contact on thermometer).

Earth fault on the high-voltage side.

A relay is also provided which operates the alarm when the starting-up process lasts longer than a preset time.

Protection against external overvoltages consists of a set of surge arresters on the transmission line starting from the station.

Both "shut-down and lock-in" and "alarm" indications are accompanied by a siren which is silenced by operating a flag relay.

New Motor Grader

An addition to the range of earth-moving machinery made by Blaw-Knox Limited, Rochester, England, is the BK10 motor grader illustrated herewith. It is powered by a 70 b.h.p. six-cylinder Leyland diesel engine and is equipped with a 10 ft. blade. This blade has replaceable cutting edges and end bits of high-carbon steel, and can be fitted with wing extensions. It has a choice of 13 pitch positions for setting to suit any type of work, it can be revolved through the full 360°, and has a vertical adjustment of 90°. The blade-lift links are telescopic and can be adjusted to five different lengths. All normal blade positions are obtainable from the driver's seat by finger-light controls which engage a mechanical drive through spring-

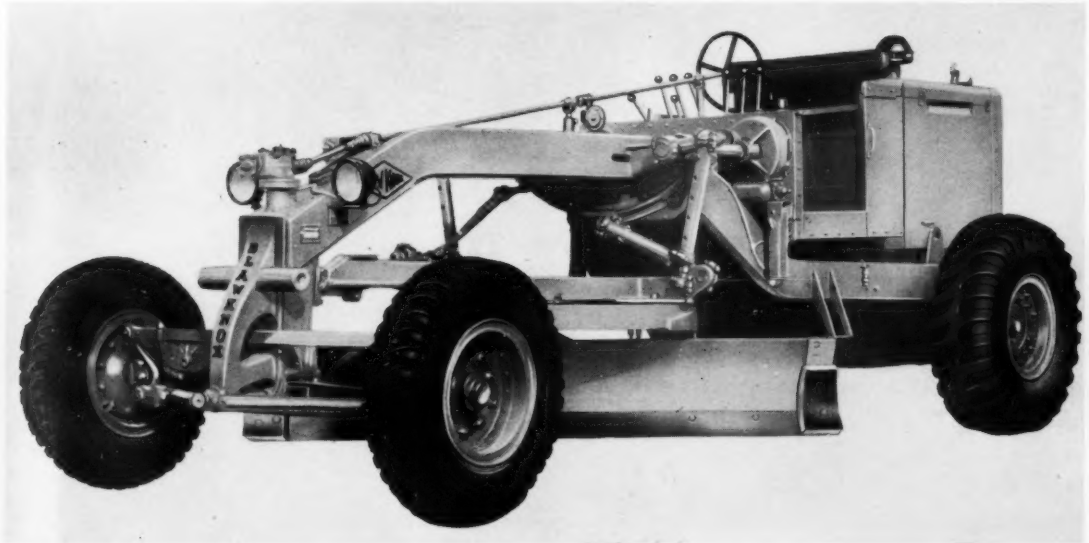

Fig. 1. Blaw-Knox BK10 motor grader

loaded dog clutches. Leaning front wheels are fitted as standard, and have a movement of 25° in either direction.

A scarifier can be supplied, provided with nine tines giving a width of cut of 42 in.

Transmission is through a single-plate clutch and a gearbox giving six forward and two reverse speeds to a solid final drive. Lockheed hydraulic brakes are fitted to the rear wheels and a hand parking brake to the transmission.

120-ton Trailer for Snowy Mountains

A ROAD trailer capable of transporting heavy engineering equipment weighing up to 120 tons has just been built for the Snowy Mountains Hydro-Electric Authority by Cranes (Dereham) Limited, Norfolk, England, and we recently visited the makers' works to examine the vehicle when it was about to undergo a service test before dispatch to Australia. The vehicle has been designed not only to manoeuvre readily and safely but also to simplify the problems of loading up at the beginning of the haul and of placing the load on site at destination—problems that can assume considerable proportions in remote localities.

To this end the trailer has been constructed on the "Meccano" principle so that if necessary it can be assembled round the load and dismantled when the load has been placed on its foundation. It has an identical eight-wheeled bogie at each end and can be towed from either end, in which event the leading bogie is steered by the tractor and the trailing bogie can either be locked or can be power-steered by the attendant on the rear platform. Alternatively this bogie can be steered by the rear tractor if one is used. The bogie wheels can be swung through 90° in either direction, so that the trailer can be turned in its own length or moved bodily sideways to bring the load over a foundation plinth.

This flexibility is enhanced by the use of a hydraulic suspension system which has been designed and patented by the builders. In addition to compensating for road inequalities this suspension functions as a jacking system whereby the trailer frame can be raised or lowered through a distance of 18 in. Thus the trailer frame can be placed on the ground for loading and can then be picked up by the jacks; alternatively the load can be slung Sedan-chair fashion. At destination, of course, the procedure is reversed, leaving the trailer frame on the ground for unloading or the load sitting on its foundation as the case may be. During transit the frame can be raised to pass over a curb or a hump in the road, lowered to pass under a low bridge, or even tilted to clear the curve of a low arch.

The construction of the vehicle can be seen by reference to the accompanying photographs. The frame proper consists of two welded box-section girders braced apart by tubular cross members. A clear loading length of 30 ft. is available, and the width can be altered in four steps from 4 ft. 6 in. to 11 ft. by inserting or removing sections into or from the cross members, which are bolted and spigoted for the purpose.

This frame is supported at either end by swan necks, which are bolted to the bogie platform and are provided with tubular cross members which can be altered to conform to the width of the frame. A rigid but readily detachable connection between frame and swan necks is obtained by a high-tensile-steel bullet-nosed pin projecting from each end of each longitudinal girder and entering a hole in the swan neck. Mating faces on the girder and the swan neck afford

Fig. 1. A view of the Crane 120-ton trailer

Fig. 2. The Thornycroft-Crane road train carrying a 100-ton test load

a rigid location, and the connection is made up solid by turnbuckle clamps.

This is a convenient type of connection in circumstances where clear space is required at the ends for the loading operation. The frame can be lowered to the ground by the jacking system about to be described, the swan necks uncoupled and the bogies withdrawn. After the load has been placed the bogies are coupled up again and the frame raised to its travelling position by the jacking system.

Each bogie comprises four suspension units, each of which carries a pair of wheels shod with $16 \times 20 \times 24$ ply Goodyear tyres and mounted at either end of a short centrally pivoted axle. Each suspension unit consists of an oil-actuated ram and cylinder having a maximum travel of 18 in. The oil chambers of the front and rear units on each side are interconnected so that vertical movement of either unit due to a road irregularity is automatically compensated by an equivalent reverse movement on the part of the other. Shut-off valves enable units to be isolated for reasons of stability, to obtain differential movement as when tilting the platform, or to release a unit for changing a wheel. To raise or lower the platform, oil is handled by a separate rotary pump mounted on each bogie and driven by an a.c. motor, which can be supplied either from the mains when the trailer is standing or from a diesel-driven generator mounted on one of the bogie platforms. Leakage through the suspension-unit glands is stated to be nil.

For steering, the four suspension units of each bogie are coupled to each other and to the steering head by links and pins; this method of connection is preferred to gears as it is virtually impossible for a unit to jump out of step. Each unit rotates on its own axis, and cylinder and ram are connected by a folding bracket so that they rotate as one piece. The rear bogie can be locked centrally by two dowel pins, but it can

Fig. 3. Frame resting on the ground for loading

be steered by the rear attendant through the agency of oil-operated rams, the controls for these rams and for jacking being conveniently grouped on the rear platform.

A Girling brake is fitted to each wheel, and the brakes on each suspension unit are applied by a compressed-air cylinder and piston connected to the pneumatic braking system of the tractor. An emergency valve on the rear platform enables the attendant to stop the train immediately without reference to the driver. A handwheel is also provided on each suspension unit for hand parking.

Two Thornycroft 250 h.p. "Mighty Antar" six-wheeler diesel tractors are being supplied to draw the trailer, one or both being used according to the load. Each tractor has a four-speed main and three-speed auxiliary gearbox, giving twelve speeds in all, and the two tractors will haul the fully laden tractor up a gradient of 1 in 7. Clutch operation, steering and braking are power assisted, and trailer brake connections are provided at front as well as rear for pushing and double-heading work. Each tractor carries a spare wheel and tyre, this wheel being carried on the back of the ballast container and raised and lowered by a hand derrick. The tyres are $14 \times 24 \times 20$ ply.

A Darlington power-driven winch with a pull of 50,000 lb. is mounted on each tractor to draw the trailer through fords or to extricate it should it become bogged. A length of 350 ft. of 1 in. diameter steel cable is carried on each winch, and passes over fairleads fitted at front and back of the vehicle. Ballast bodies will be built in Australia, and temporary bodies have been fitted for tests in England.

An all-metal cab is fitted, equipped with an electric fan and a Clayton-Dewandre heater and windscreen defroster. A Tannoy telephone system affords communication between driver and trailer crew and between front and rear drivers.

Fig. 2 shows the road train undergoing a test on English roads before shipment to Australia. The trailer was taken from Dereham to the works of the General Electric Co. Ltd., Birmingham, to pick up a 100 ton stator for a hydrogen-cooled steam turbo-generator, which it delivered to the Uskmouth generating station at Newport, Mon., via Worcester, Gloucester, Ross-on-Wye and Monmouth—a route involving city traffic, narrow bridges and several hills with steep gradients. The gross running weight of the road train was 223 tons, and the test was carried out by Robert Wynn & Sons Ltd., a South Wales firm of heavy-haulage contractors, under arrangements made with the manufacturers of the road train and with the consulting engineer in London for the Snowy Mountains Hydro-Electric Authority.

While we were at Messrs. Crane's works we saw an even larger trailer under construction for British Road Services. It is designed to carry 200 tons and will have 12 wheels on each bogie.

Abstracts from the World Technical Press

Improving Power Factor in HT and LT Systems

The regulation of wattless or "inactive" current is suggested as a means of improving the power factor. The author purposely uses the term "inactive" instead of "reactive," as applied to current and power, claiming that "reactive," as used heretofore, conveys the idea of a vectorial rotation of 180° in relation to active current or active power, whereas the rotation is physically only 90°.

Several methods are advocated. One consists in using synchronous machines capable of delivering or absorbing inactive current, set up at points convenient to the operator, generally at the receiving end of a H.T. line equipped with step-down transformers.

Another solution uses batteries of condensers located as close as possible to the consumer; their size must be determined so as to offset the inactive current absorbed by the consumer, without enabling the inactive current to return to the incoming line. Necessarily, the condensers must be regulated by strong and quick-acting contactors actuated by reliable relays in accordance with either time, voltage or inactive current.

A third method consists in fitting the step-down transformers with stepped contactors which can be set under load.

The regulation of inactive power is tied to the presence, on either side of the transformer, of generators capable of keeping up the voltage; if either of these happens to fail, regulation of inactive power becomes impossible, and regulation of voltage must be resorted to. Thanks to the regulation of the inactive power, not only can a part of the inactive power supplied by the capacity of the line be evacuated towards the consumers but the active power can also be accompanied by a perfectly adapted part of inactive power. On the other hand, regulation of the voltage can also contribute to the improvement of the power factor; for this purpose, the regulation of the voltage must be made responsive to inactive power through lowering the duty value of voltage when the output of inactive power increases. This brings about a reduction in the consumption of inactive power.

It is obvious that this regulation of tension can be applied independently of the regulation of inactive power, both regulations thus contributing to the improvement of the power factor. (Ch. Jean Richard, *Bulletin de l'Association Suisse des Electriciens*, Vol. 44, No. 1, January 10, 1953, p. 20, 2 pp.)

Oued el Abid Development, Morocco

In this article, M. G. Gravier, general manager of "Energie Electrique du Maroc," describes the civil-engineering works of this important development, briefly reviewed in the September 1952 issue of WATER POWER, p. 338.

The Bin el Ouidane dam is an arched structure 135 m. high, with a thickness of 32 m. at the base and 5 m. at the top, and a crest 260 m. long; it consists of blocks about 15 m. long connected together by grout joints injected before the reservoir was filled; extensive grouting had to be carried out to improve the imperviousness of the otherwise sound foundation rock, which was reached after removing an alluvium deposit extending 25 m. deep below the Oued bed.

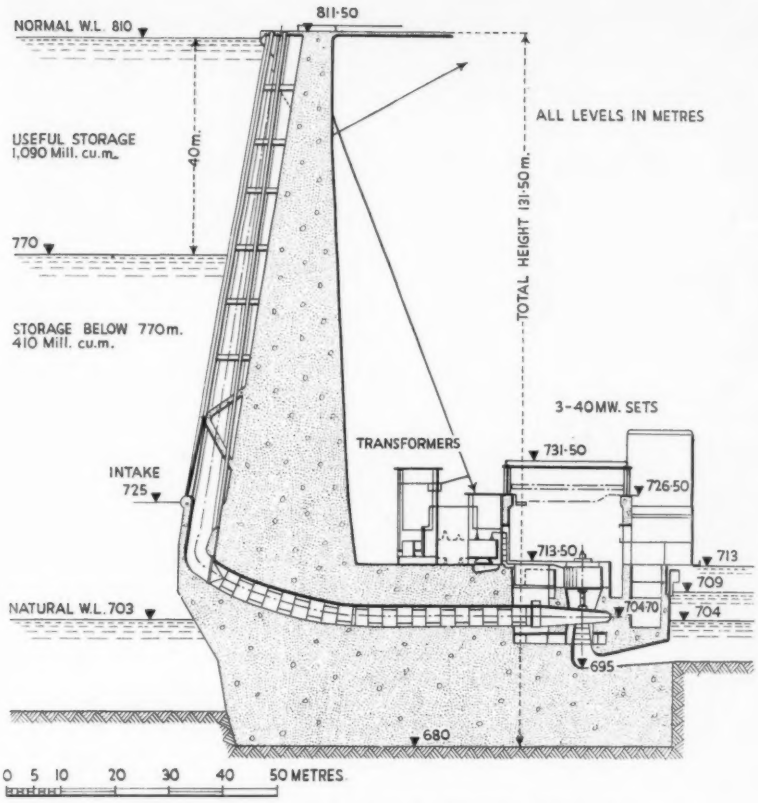

Fig. 1. Cross section through the Bin el Ouidane dam

Flood control is effected by means of a ski-jump spillway set up close to the right-bank abutment of the dam, and designed for a discharge of 3,500 cu. m. per sec. The works required altogether the placing of 450,000 cu. m. of concrete. Concreting, which started in January 1951, proceeded rapidly, and no more than 20,000 cu. m. remained to be placed in October 1951, most of it in ancillary works and at high-level spots where steel reinforcement was used.

The Ait Ouarda dam, 4 km. downstream from Bin el Ouidane, will be much smaller in size, requiring but 29,000 cu. m. of concrete, of which 22,000 cu. m. were already placed last January. Compared to the 1,500 million cu. m. of water stored at Bin el Ouidane, the Ait Ouarda reservoir is no more than 2·5 million cu. m. in capacity, and will act as a compensation pool between the two plants, so as to ensure their daily operation independently of each other.

The water level at Ait Ouarda will be raised by a mere 20 m. but just as at Bin el Ouidane, deep excavations had to be made in the alluvium below the Oued bed before adequate foundation rock was found; in fact the height of this dam above foundations does not exceed 40 m. The dam proper is a thin cylindrical arch, 5 m. thick throughout, resting on a bed of foliated limestone; here also extensive grouting was necessary.

From the Ait Ouarda dam, a straight tunnel 4·5 m. dia. with a discharge capacity of 48 cu. m. per sec. traverses the Liassic strata of the Tazerkount mountain to convey the water above the plain. Out of a total length of 10,570 m. no less than 9,825 m. offer no possibility of providing for intermediate construction adits; the head at the downstream end of the tunnel is 35 m. against 18 m. at the upstream end. The driving of this tunnel encountered various difficulties, owing to the presence of long stretches of marly-gypseous or water-bearing strata; in spite of the additional work involved (excavations, grouting, reinforced lining, etc.), driving proceeded at the rate of 120 m. a month. On October 15, 1952, 8,120 m. of the tunnel had been excavated to full cross-section, leaving a gap of 2,350 m. between the upstream and the downstream section; it is expected that the two sections will meet at the end of this year. The surge tank near the downstream end of the tunnel is remarkable for its large size: 30 m. dia., 26 m. high, and connects with the penstocks which feed the turbines of the Afourer powerhouse, ensuring a head of 225 m.; these penstocks, 567 m. in length and 2·6 m. dia. consists of self-hooped (steel cables) pipes. Completion of the whole work is scheduled for the beginning of 1954. (G. Gravier, *Wasser- und Energiewirtschaft*, Vol. 45, No. 1, January 1953, p. 1, 9 pp., 13 ff.)

Tests on 220 kV Shell-Type Transformer

From a group of four identical single-phase transformers supplied by Ateliers de Constructions Electriques de Charleroi to the Pragnères development of Electricité de France, one was taken to the EdF research centre at Fontenay-aux-Roses to undergo exhaustive tests. These units are of the shell type, each being rated at 20,000 kVA 63/128 kV giving 220 kV between phases on the high-voltage side when star connected. The tests included dielectric tests with impulse waves, electromechanical tests on dead short-circuit, and thermal tests. On the impulse test the high-voltage winding, guaranteed for 1,050 kV with full wave, resisted 156 tests with full and chopped waves between 1,000 and 1,550 kV. On the second and third tests at the latter voltage an arc occurred which could not be located, but at the end of these tests the high-voltage windings again withstood numerous full-wave tests at 1,050, 1,150 and 1,210 kV, comprising more severe tests than those specified in the guarantee. After these impulse tests the transformer withstood four dead short-circuits on the EdF 220 kV network. From these and other tests it is concluded that the manufacture of 330 and 400 kV transformers could be accomplished with certainty of success.

A second article in this issue gives a detailed description of the manufacture of ACEC shell-type transformers. (H. Chevalier and E. Grandry, *ACEC Charleroi*, No. 4, 1952, p. 30, 50 pp., 38 ff. Also E. Rousseaux, p. 2, 27 pp., 49 ff.)

Association for the Study of Hydro-Electric Development in the Austrian Alps

The whole of the March issue of the OZE (*Oesterreichische Zeitschrift für Elektrizitätswirtschaft*) is devoted to the above Association which was founded in Innsbruck on December 1, 1952, by the Deutsche Verbundgesellschaft, Electricité de France, SENEL and Oesterreichische Elektrizitätswirtschaft A.G., representing Germany, France, Italy and Austria respectively (see page 242 of this issue).

The foundation of the Association is due to the initiative of Dr. Stahl, Manager General of the Oesterreichische Verbundgesellschaft, and its ultimate purpose is to promote the construction of hydro-electric plants in Austria, and to export the surplus energy generated to the three other countries. The initial purpose is to make a thorough study of the projects worked out so far, to select those which appear most suitable for development, and to create the conditions necessary to the financing of the undertakings to be set up.

The German interest in the scheme is broadly set out in a contribution of the Deutsche Verbundgesellschaft, Heidelberg: Austro-German co-operation for the development of Alpine water power dates as far back as thirty years ago, and has already resulted in the setting up of storage reservoirs and power plants on the Ill. The river offers, however, further possibilities of development which are worth investigating.

The French point of view is explained at length by MM. Pierre Grézel and Louis Castillon, of Electricité de France. In the first part of their article, the development of energy exchanges between France and her neighbours is reviewed in detail while the second part examines the possibility of Franco-Austrian relations in this field. Since the two countries have no common frontier, transit through a third country must be resorted to, and it is suggested that, for instance, energy required by France might be supplied by Austria to an Italian concern or group, while another Italian concern or group would export its available energy to France.

Prof. Ing. Marco Visentini, chairman of the SENEL group, deals himself with the Italian aspects of the question. With the exception of the Alpine regions, Italian rivers do not lend themselves very well to development. The production of hydro-electric power in Italy has its source in about 150 storage reservoirs with an aggregate useful capacity of 2,900 million cu. m., corresponding to a production of 3,400 million kWh. The share of the catchment areas bordering on Austria amounts to about 29 per cent. of the total Italian production. Up to date, slightly more than a half of Italy's potentialities has been developed, and the rest offers but scanty possibilities of economical development. The establishment of closer relations with Austria as a prominent exporter of hydro-electric energy will therefore be particularly welcome in Italy.

Austrian contributions to this issue of OZE comprise: "Considerations on the Creation of the Association," by Dr. R. Stahl; "Management Programme of the Association," by Dipl. Ing. Ernest Werner; "Alpine Water Power in Austria," by Dipl. Ing. Dr. Osgar Vas, Vienna; "Prerequisites of the transport of energy from the stations projected in Western and Eastern Tyrol," by Dipl. Ing. F. Hintermayer, Director of the Verbundgesellschaft in Vienna; "Control of international energy exchanges and of frequency co-ordination," by L. Bauer and W. Ehrbacher.

In addition, the new Austro-Italian overhead transmission line, now in course of construction between Pelos and Lienz, is the subject of two articles: Dr. Ing. Antonio Rossi, Manager General of the SADE concern, Venice, deals with the Italian section of the line, while Herr H. Kalig, Director of the Verbundgesellschaft in Vienna, reviews the Austrian section. (*Oesterreichische Zeitschrift für Elektrizitätswirtschaft*, Vol. 6, March 1953, pp. 65 to 114, 30 ff.)

Induced Rain Precipitation

A survey is given of the positive results achieved in experimental meteorology for the purpose of increasing precipitations in regions where such an increase is required for irrigation or electricity generation; the attenuation of hailstorm hazards is also considered. Diagrams drawn in agreement with the observations made on the west coast of the U.S. show the changes brought about by artificial means in the distribution of precipitations.

The author claims that the possibility of induced rain precipitation can no longer be denied; new branches of physical experimentation are beginning to take form, and may soon contribute to the solution of important problems closely connected with the supply of water and energy. It is, however, essential that the question should be approached without any bias and with the necessary scientifical knowledge, if clear and reliable deductions are to be drawn on the economic application of these new methods of experimental meteorology. (R. Sänger, *Bulletin de l'Association Suisse des Electriciens*, Vol. 44, No. 5, p. 189, 6 pp., 6 ff.)

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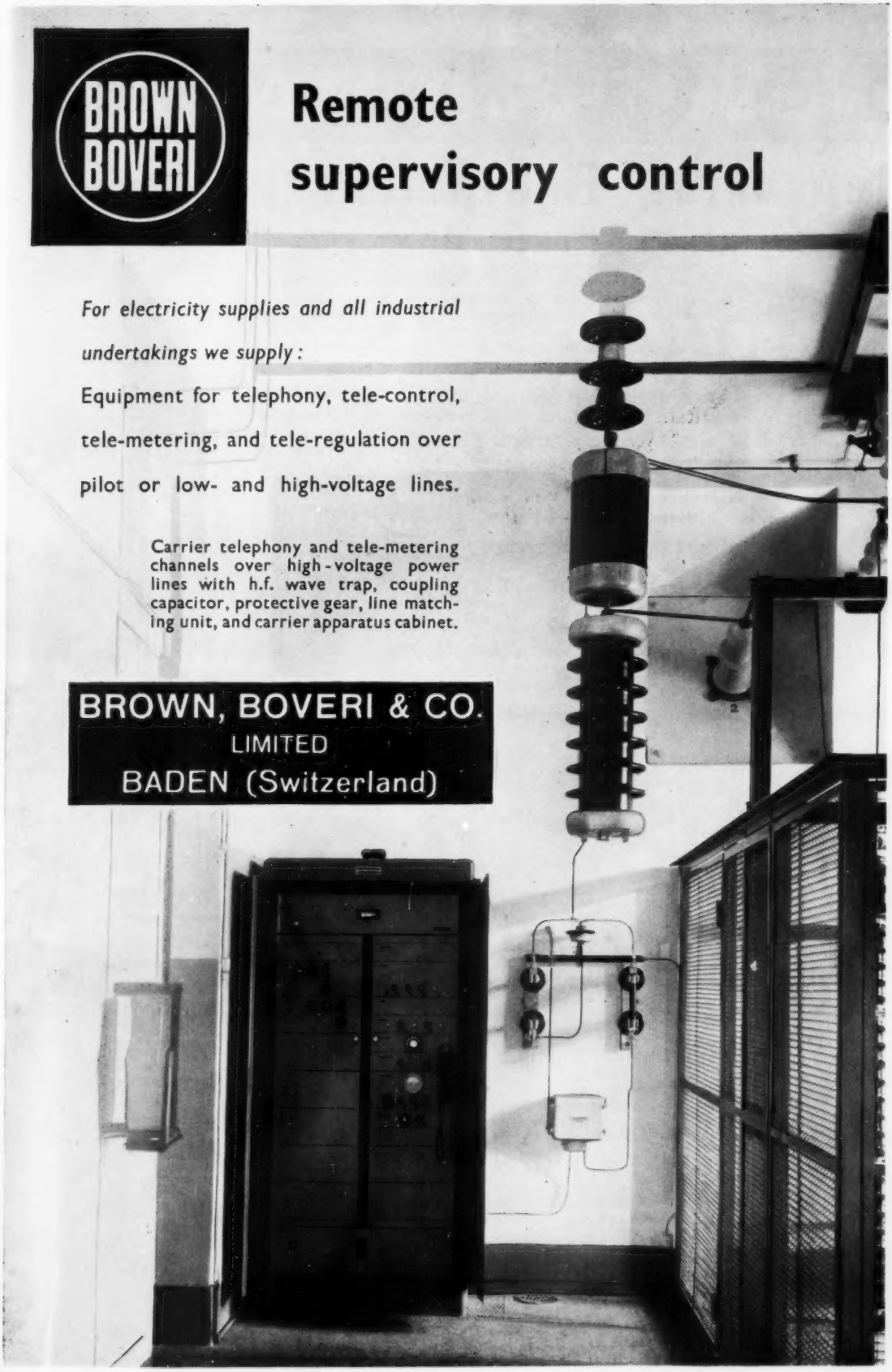

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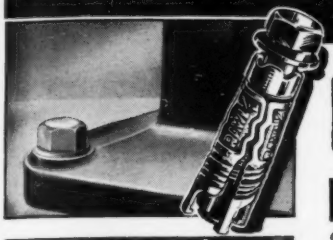

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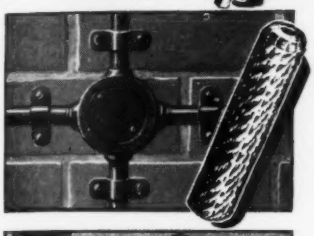

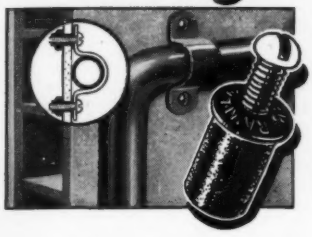

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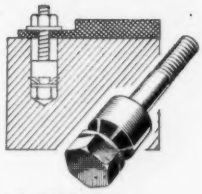

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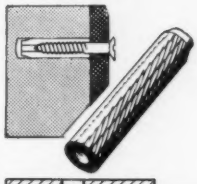

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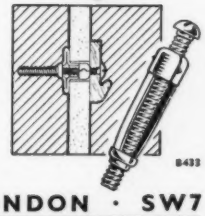

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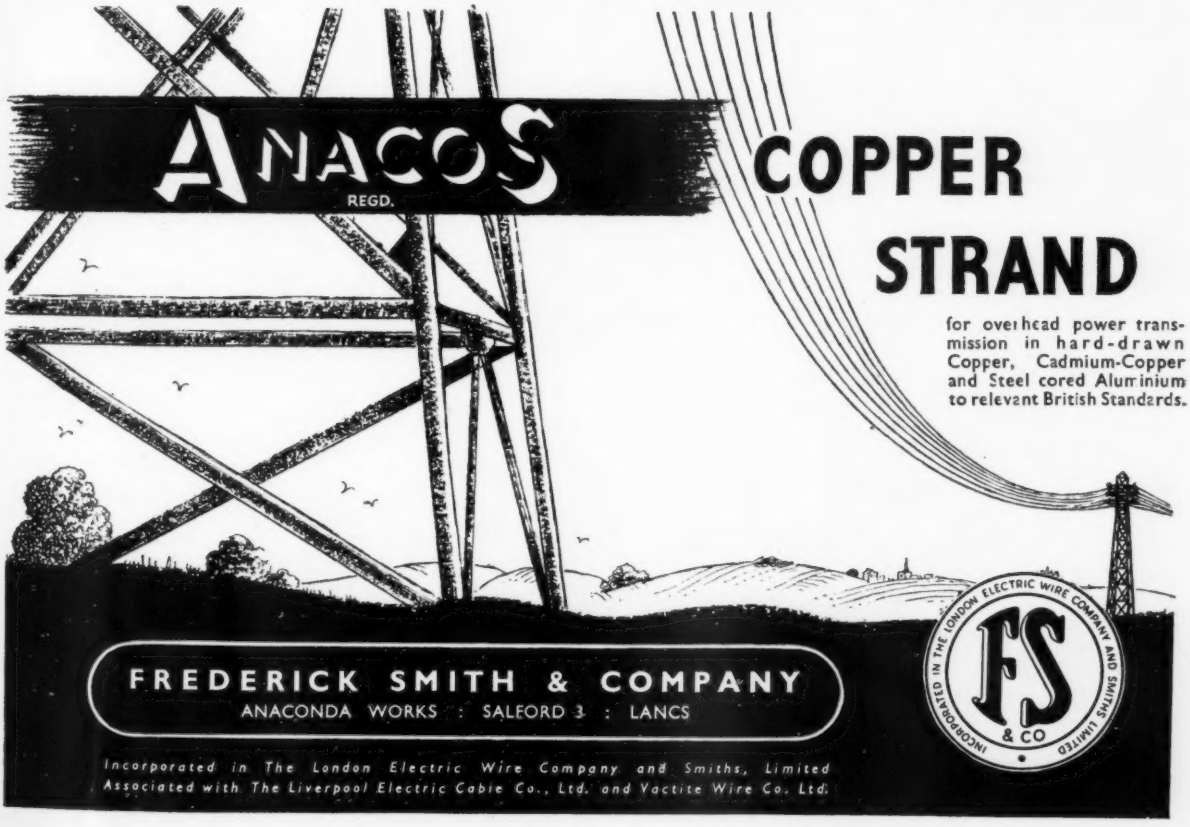
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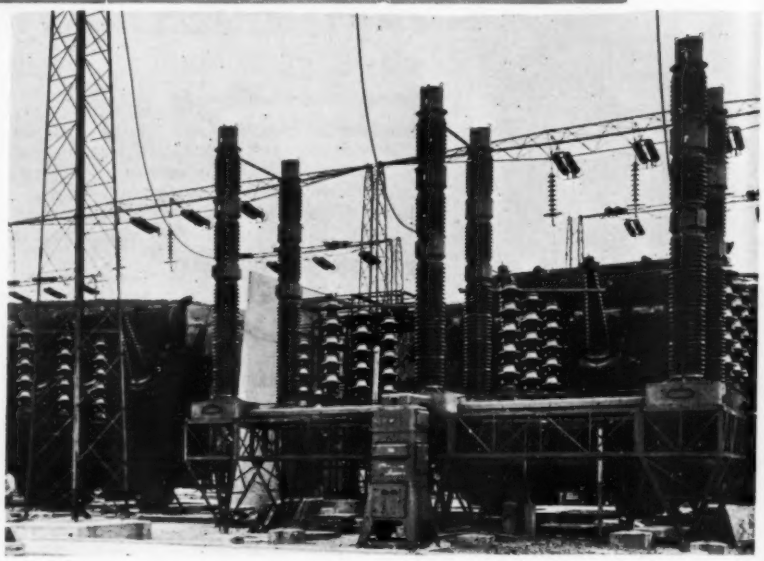

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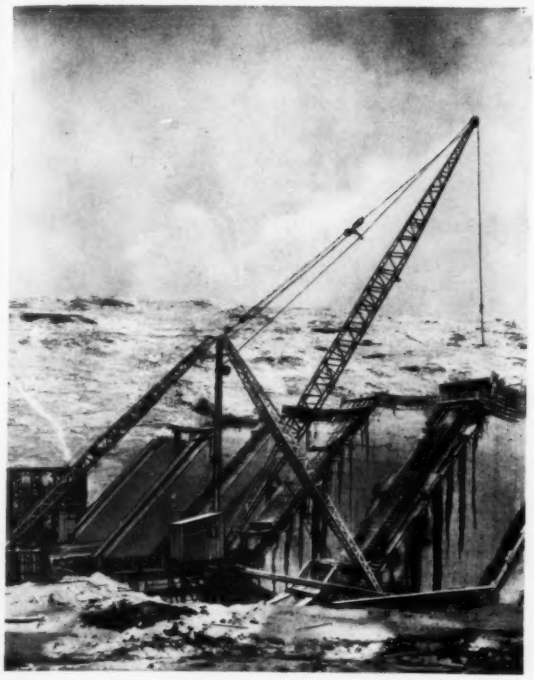

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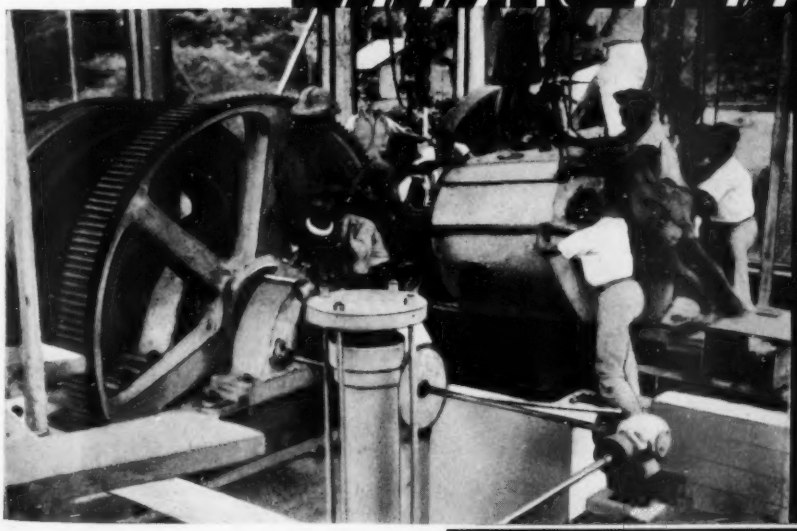

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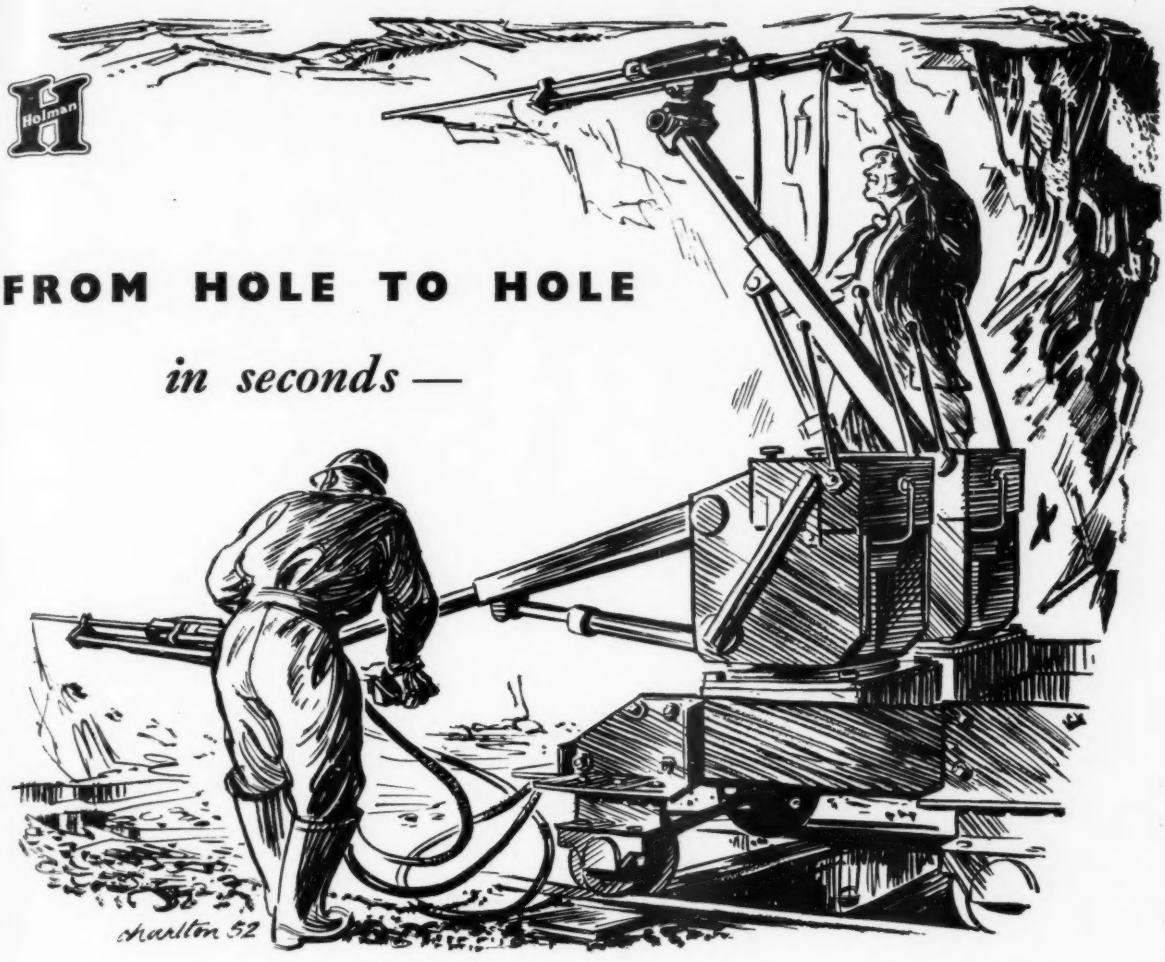

FROM HOLE TO HOLE

in seconds —

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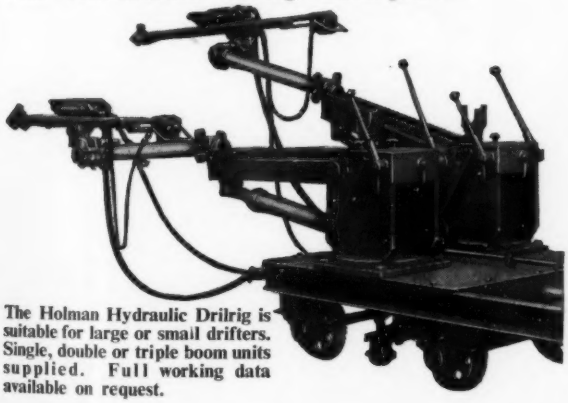
In every type of mining undertaking the Holman Hydraulic Drilrig means easier drilling, faster drilling and cheaper drilling. Compare these advantages with conventional drilling techniques :—



The Holman Hydraulic Drilrig is suitable for large or small drifters. Single, double or triple boom units supplied. Full working data available on request.

- **SPEED :** movement from hole to hole is a matter of seconds, making drilling with long-feed drills and tungsten carbide-tipped Holbits the fastest technique obtainable.
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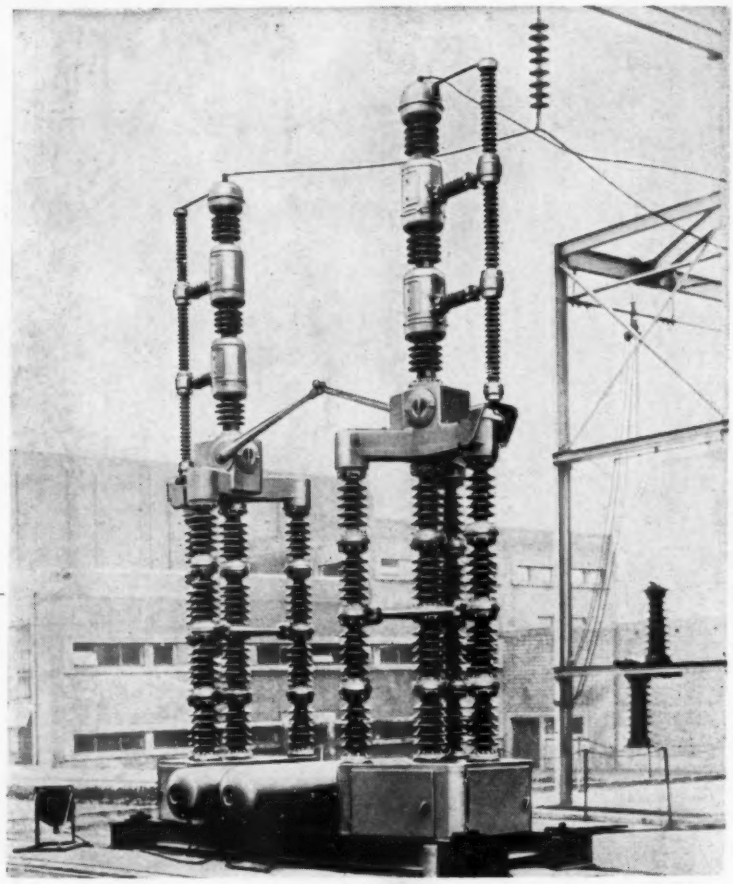

Illustrated is the 275kV, 7500 MVA six-interrupter circuit breaker, one of the range of 'ENGLISH ELECTRIC' high voltage air-blast circuit breakers using common interrupters and other standard parts. This circuit breaker is one of those selected by the British Electricity Authority for use on the British Super Grid.

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